Regulating Network Access Prices under Uncertainty and Increasing Competition

- The Case of Telecommunications and Local Loop Unbundling in the EU

M.Sc.-thesis

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Abstract

When network industries such as telecommunications, gas and electricity are liberalised, it is necessary to "open up the networks" by allowing competitors access to parts of the incumbent's infrastructure. Network industries are characterised by large economies of density, monopoly over access and for some network industries also the existence of network externalities. These characteristics provide the incumbent network operator with major advantages over entrants. Construction of competing networks, in particular access networks, is typically not economically viable. Hence, there is a need for (regulated) access.

Due to the important role that network industries play in society and the major change that these industries are currently undergoing, the question of how to regulate network access has become one of the most, if not the most, important question in regulatory economics.

The objective of the thesis is through an economic and brief legal analysis to investigate under which conditions access to networks should be required, how the price of such access should be determined in order to obtain desired regulatory objectives, and in particular to investigate the regulatory implications of uncertainty.

The thesis focuses on the telecommunications industry. In particular it is investigated whether incumbents should be required to unbundle their local loops - the lines connecting the customers to the network - and how to regulate the price of such access.

From a theoretical point of view, the main contribution of the thesis is a formal analysis of the regulatory implications of uncertainty. While regulatory uncertainty, technological uncertainty and demand uncertainty are substantial, particularly in telecom, these uncertainties are largely overlooked in the literature of access pricing. Drawing on the main insights of the new investment theory known as real-option theory, a simple formal framework is constructed in order to evaluate the regulatory implications of uncertainty for the access-pricing problem.

Regarding the academic level of the thesis, it has been a goal to make it interesting for economists (or students of economics) who are already familiar with the access-pricing problem as well as interesting for economists who are not. The mathematical level does not require any particular mathematical background other than what can be expected from an economist. Mathematics is only employed where the thesis contributes to the existing literature on access pricing. Where the necessary economic insight can be explained intuitively, time is not wasted copying the proofs and formal derivations of other scholars. Instead, the thesis focuses on the policy implications of the provided economic insights, in particular those implications, which are relevant for a future regulatory framework for local loop unbundling in the EU.

Based on a brief legal analysis of EU competition law and in particular recent decisions by the European Court of Justice it is concluded that entrants are unlikely to be granted access to the incumbents' local access network based on EU competition law alone. Based on this conclusion and an investigation of the economic characteristics of network industries, it is concluded that there is a need for sector-specific regulation of network access. Having evaluated different pricing principles such as marginal costs, Long Run Average Incremental Costs (LRAIC), Ramsey pricing, the Efficient Component Pricing Rule (ECPR) and a global price cap on the basis of a brief discussion of the regulatory objectives, the thesis concludes that access prices should be set at LRAIC plus a mark-up for joint and common costs including a reasonable return on the invested capital - at least in telecom.

Regarding the local loops, the thesis concludes that entrants should be granted physical access to the incumbent's local loops at cost-based prices, determined as Long Rung Incremental Costs (LRIC) plus a mark-up for joint and common costs including a reasonable return on the invested capital.

Such access is necessary, first of all, to ensure competition in the future market for high-speed Internet access. Second, because it allows competitors to offer integrated products such as the Danish Duet system, which integrates mobile and fixed telephony, in competition with the incumbent. Finally, it increases local competition for basic voice telephony and allows entrants to use innovative technologies and pricing schemes.

The real-option analysis provides two main insights: First, an additional argument for local loop unbundling: It reduces regulatory uncertainty for the incumbent as well as for entrants, who know that unbundling is likely to be required sooner or later. Second, if access provision by a regulated operator requires investments in either upgrading an existing network or in constructing a competing network, and these investments 1) are irreversible, 2) involve uncertainty over future net revenues and 3) can be postponed; then the regulated (access) price, in order to create efficient (dynamic) investment incentives, needs to include an option premium on top of LRIC to compensate the regulated operator for the lost option value, associated with investing today instead of waiting until some of the uncertainty is resolved. This insight applies to regulation in general, not only to regulation of access prices.

With regard to the local loops, already in the ground, such an option premium is unnecessary and would only imply a transfer of wealth from entrants to the incumbent, thus contradicting the need for "levelling the playing field". Hence, an option premium should not be added.

On the other hand, if regulators want to regulate the price of access to alternative (future) access networks based on technologies such as cable television, UMTS (3rd generation mobile) and Fixed-Wireless-Access technologies, this option value cannot be ignored. Estimating these option premiums correctly, however, is at best very complicated. A practical solution is to allow a relatively short depreciation horizon.

Preface

I was introduced to the access-pricing problem during a graduate course of regulation with Prof. Joseph Farrell at UC Berkeley in spring 1998. At Berkeley, I also became interested in telecommunications. Due to my interests in telecom and regulation, I applied as a trainee to the European Commission DG13/A1, which deals with telecom legislation in the EU. Here I worked as a trainee (stagiaire) from 1 October 1998 to 1 March 1999. During this period I became particularly interested in the issue of local loop unbundling (LLU) in the EU. At the time, LLU had only been required in a few EU Member States, including Denmark, and the Commission did not hold any opinion about whether to recommend LLU in the EU or about the principles for determining the access price for such loops. It had only launched a study (OVUM 1998) on the technical issues.

Due to the obvious reasons for requiring such access as well as the need for establishing guidelines to increase regulatory uncertainty, I was convinced that the subject would become a main regulatory issue in year 2000. The amount of policy implications was one of the main reasons that I decided to deal with access pricing and LLU in my thesis. First of all, from my course at Berkeley, I knew that the subject contained some theoretically interesting economic and legal aspects. Secondly, during my period with the Commission, I came across a conference paper, which verbally presented the real-option aspect of pricing access to unbundled local loops[1] - an idea, which has not yet been incorporated into the literature of access pricing. Thus, I saw a possibility to work with some very recent economic theory as well as to do some original work on the subject through a formal application of real-option theory to the access-pricing problem. On my return from the Commission, I had to finish my course work before I could begin writing the thesis. Among other subjects I followed a course on real options ("Investeringsteori").

To broaden the scope of the thesis and to focus on the theoretical issues, I decided to deal with the problem of access pricing in a general way, but using telecom and local loop unbundling for exemplification.

The thesis has been written between 1.12.1999 and 10.04.2000. I have not received any help, nor had any job or access to any kind of information not available to the public. I thank my adviser Birgitte Sloth for very useful comments on an earlier draft.

The thesis and relevant links are available at http://www.image.dk/~holmside/thesis.htm

[1] Cave & Crowther (1998): "Infrastructure & Service Competition: The Law and Economics of Local-Loop Unbundling".

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"Allowing entry into regulated monopolies undermines the traditional structure of these industries and of regulation itself. The problem is that regulators and companies, to say nothing of regulatory economists, were flying blind. Once entry was allowed, the consequences were not clearly foreseen. The contradictions created are still to be resolved". Crew and Kleindorfer (1999)

Chapter 1:

Introduction, objective and outline of the thesis

1.1 Introduction

One of the most exiting and economically most significant political decisions taken in the OECD countries in the 1990's, has been the decision to liberalise most of the network industries such as telecommunications, electricity and gas. The liberalisation process has only recently begun and will dramatically change the economics of these industries over the next decade. A change, that will affect almost every citizen in the developed countries on an almost daily basis.

In order to introduce viable competition into these network industries, it has been necessary to "open up the networks" by allowing competitors access to parts of the incumbent's infrastructure. Consequently, the question of how to regulate network access has become one of the most, if not the most, important question in regulatory economics.

Access to essential facilities is an old economic and legal question, originating from the need for railway companies to gain access to the bridges of competitors and for ferry companies to gain access to harbours. The economic rationale for regulating access is therefore well described in the literature of law and economics. The liberalisation of the network industries, however, has created a need for further investigation of the access-pricing problem and a whole new literature on the subject has evolved in recent years.

The purpose of this thesis is to present and discuss the most important issues that regulators have to consider 1) when they evaluate whether or not to grant access to a network, and 2) when they subsequently have to decide whether and how to regulate the price of such access. The core analysis is based on economic analysis. In addition to this, an attempt to perform a legal analysis of existing EU competition law is also made in order to evaluate whether access can be required on the basis of competition law alone, or whether such a step necessitates sector-specific regulation. The question is a strongly debated subject among legal scholars so no firm conclusions will be drawn from the analysis. No analysis of the access problem would be complete without a consideration of the legal aspects.

With regard to the access price, a discussion and an evaluation of different regulatory approaches form the basis of several recommendations for a proper pricing methodology. In particular, the thesis explores the impact of uncertainty - a subject, only recently studied by academic scholars. Apparently, no formal literature yet exists on this subject. Obvious uncertainties are involved with forecasting future technology, demand, regulation, interest rate etc. However, these uncertainties are largely ignored in the traditional analysis. This is why they will be explored in more detail in this thesis by drawing on the recent insights into the investment decision provided by the literature on real-option theory.

The theoretical discussion is kept as general as possible, but for exemplification the thesis throughout focuses on telecom where the access problem is more complex than it is in the other network industries. Moreover, the liberalisation process has progressed more rapidly in telecom.

To illustrate many of the regulatory issues discussed in the thesis, in particular the issue of uncertainty, the thesis ends with a 'case study' of the pricing of unbundled local loops (the lines connecting telecom subscribers to their network) in the EU. The question of whether or not to unbundle these local loops, and in particular how to determine the price for access to them, will be a very important issue, if not the most important issue, for European telecom regulators in the upcoming couple of years.

1.2 Objective

The objective of the thesis is, through an economic and brief legal analysis, to investigate under which conditions access to networks should be required, how the price of such access should be determined in order to obtain desired regulatory objectives, and in particular to investigate the regulatory implications of uncertainty. The focus will be on the telecommunications industry and the pricing of unbundled local loops in particular.

1.3 Outline

The thesis is organised as follows: Chapter 2 describes the key economic characteristics of network industries in order to understand why network access may be required. Chapter 3 then discusses the essential facility concept applied to network industries and analyses the essential facility doctrine in EU competition law with the purpose of evaluating whether network access can be required based on EU competition law alone. The chapter finishes by discussing whether the need to regulate access is eliminated with the (future) introduction of multiple competing access networks.

Having established the need for regulating access, chapter 4 explores some overall issues regarding the regulatory approach and sets out the regulatory objectives that needs to be considered when determining the access price. Chapter 5 evaluates different pricing principles based on these regulatory objectives in order to present a recommendation on how to determine the access price. The chapter ends with a brief presentation of the current EU legal framework for pricing access/interconnection in telecom.

In chapter 6 and 7 we then introduce uncertainty and discuss the implications of applying real-option theory to the access-pricing problem. Chapter 6 briefly presents the main insights of real-option theory intuitively as well as formally in order to provide readers, unfamiliar with real-option pricing, with the understanding necessary to evaluate its application to the access-pricing problem. Chapter 7 then extends these insights to the access-pricing problem and discusses the regulatory implications.

The discussion of the network-access-pricing problem is closed by focusing on a particular 'case' in chapter 8: The case for requiring access to unbundled local loops in the EU and in particular the main issues involved when determining the price of such access. The case serves as an exemplification of many of the issues raised in the thesis, in particular the issue of uncertainty.

Chapter 9 summarises the main insights and conclusions of the thesis, focusing on the policy implications.

Chapter 2:

Characteristics of network industries

2.1 Network characteristics

Industries like electricity, telecom, gas, railway etc. are typical examples of network industries in the sense that a substantial part of the products they produce consists of transport from one destination to another via a network.

The simplest kind of network is illustrated in figure 2.1 (a). It can be a *one-way network*, say a gas network or a cable-television network with gas or television signals being distributed to consumers from a source A; or it can be a *two-way network*, say telecom or railway network, connecting subscribers or train stations via a switch/central station, A.

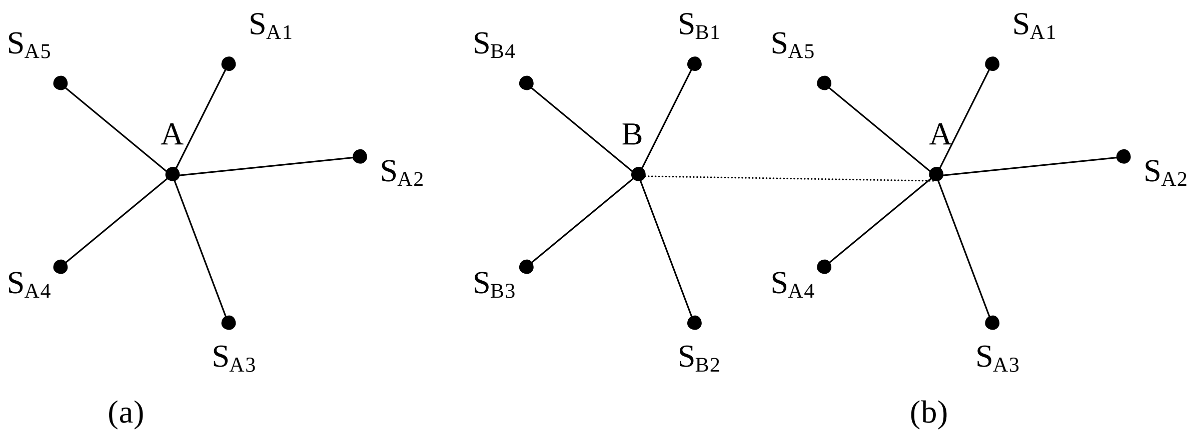

Figure 2.1 - Networks

Three key characteristics separate network industries from other industries:

(1) Economies of density

(2) Network externalities (for two-way networks)

(3) Monopoly over access

2.1.1 Economies of density

The cost per subscriber falls with the number of subscribers in a given area. The cost of establishing the switch or the core network is more or less independent of the number of subscribers and the cost of adding a subscriber amounts to the cost of connecting the subscriber to the existing network. Think for instance of cable television (CATV) [2]. The major cost of establishing the network is to dig down the cables. Therefore, it is extremely expensive to deliver CATV to the first customer at a given road (you have to dig up the entire road). But as soon as the main cable is in place, the cost of connecting more houses to the cable amounts to laying down a cable from the house to the road. Economies of density resemble economies of scale and can also lead to a natural monopoly. But one should distinguish between the two because economies of scale relate to the number of customers, whereas economies of density relate to the density of customers - the number of customer within a given area.

2.1.2 Network externalities

When an additional subscriber becomes connected to a (two-way) network, the utility increases, not only for this subscriber but for the other subscribers as well. An obvious example is voice telephony. When a subscriber is added to the network, other subscribers benefit as well because they are now able to contact and be contacted by this subscriber. In other words, the utility of being connected to a given network depends positively on the size of the network[3].

This explains why interconnection between (two-way) networks is so important, given that it is very costly to be connected to multiple networks. The dashed line in figures 2.1 (b) illustrates such interconnection. It allows customers on each network to contact each other as if it was one network, thereby drastically increasing the value of being connected. Enforcing interconnection is therefore crucial from a welfare point of view. However, it is probably even more important from a competition-policy point of view. If it were not due to the strong strategic incentive to behave anti-competitively, interconnection would namely always be provided by the market because it increases subscribers' willingness to pay. The point is, though, that if two networks that compete over the same customers are not interconnected, the larger network has a substantial advantage compared to the smaller network. This is so because the value of

[2] Appendix E presents a list of the abbreviations used in this thesis.

[3] One could also state this more technically: the addition of subscriber S_{n+1} to a network with n subscribers creates 2n new potential goods, where a good is transport from one subscriber to another (Economides 1998).

subscribing to the larger network is higher than the value of subscribing to the smaller network, all other things equal. An incumbent network operator therefore has a natural incentive to refuse interconnecting with entrants in order to gain a competitive advantage, if not to entirely eliminate competition - *foreclose the market*. Enforcing interconnection is not enough, though, since the incumbent alternatively can set the interconnection price so high that it corresponds to a denial of access. Thus, it is also necessary to regulate the terms of interconnection and in particular the price of such interconnection[4].

2.1.3 Monopoly over access

As long as a consumer is connected to a given network, the operator of this network holds a monopoly over access to this consumer. In telecom, a subscriber to network A, S_A, who wants to call a subscriber to network B, S_B, needs access to network B - or at least the local loop, connecting subscriber S_B to network B - in order to terminate (deliver) the call. This is true also with many competing networks.

This crucial point is often overlooked by regulators or at least not incorporated into legislation. In late 1999, the National Regulatory Authority (NRA) in Denmark, Telestyrelsen, e.g. allowed a competing access provider, Sonofon, to charge twice as much for call termination as the other operators, including the incumbent, Tele Danmark. This was allowed because the price of call termination is only regulated for operators with a market share above 25%. This seems to be the case in most EU Member States and appears to be based on the belief that

[4] The question of access to networks is similar to the question of *compatibility of standards* due to the existence of network externalities. The more people who use a given standard, say the operating system *Windows* or the video format *VHS*, the more attractive this standard will be for future customers. Network externalities may be so important that customers may choose the most common standard even though superior standards exist. A classical example is the QWERTY keyboard, where the keys were originally placed in order to reduce the likelihood of jamming. The keyboard has survived even though superior keyboards have been developed.

If two standards are compatible, products made for one of the standards can be used in combination with the other standard as well. Just like dominant network operators, proprietors of a dominant standard technology have a strategic incentive to make it incompatible in order to gain a competitive advantage, by making competing standards sufficiently unattractive to consumers. On the one hand, compatibility increases the value to consumers by extending the possible use of the product. On the other hand, it makes less widespread standards much more attractive by extending the value of the network externalities to them. Without regulation, a firm's decision about compatibility will be a balancing of (strategic) costs versus benefits. One thing is certain: Consumers lose with incompatibility, because the value of the indirect network externalities (between standards) is eliminated. The ultimate type of compatibility is provided by the so-called *open standards*, where the proprietary rights to a given technology or intellectual property are made available to all interested parties. Well-known examples are the GSM, Linux, HTML and Java standard. For more information on network externalities and compatibility see e.g. Economides and White (1998) which include a comprehensive list of references to the literature. See also Economides' web-site on networks: http://raven.stern.nyu.edu/networks regulation is not necessary in a competitive market with many operators. The problem with this line of reasoning is that the market for call termination is *not* competitive. The calling party, S_A, who is paying for the call, can not choose between operators for call termination. He is obliged to use operator B, via his own operator, to call customer S_B. Network A pays an access charge to network B. It is then up to network A whether this charge is passed on to the customer. The point is that there is no competitive pressure on network B to reduce its price for call termination[5].

If consumers are altruists (or want to receive many calls), the price paid by other people calling the consumer will be a relevant parameter for a consumer when he chooses between operators/access providers. Consequently, some competitive pressure may exist. However, competition policy or regulation can not be based on this assumption.

If legislators do not want to regulate call-termination prices of non-dominant operators, they can alternatively invoke a principle of reciprocity. If network A charges a high price for terminating calls originating on network B, network A will have to pay a similarly high price for terminating calls on B's network[6].

2.2 Retail pricing and the access deficits

2.2.1 Two-part-tariffs and the access deficit

For all networks, costs can be separated into two main categories: Firstly, the costs of getting connected to the network and staying connected to the network and secondly the costs of transport. Connection costs are fixed - independent of the amount of traffic. In most industries the total billing to the consumer has consequently been divided into a fixed rental fee and a traffic-dependent price such as a price per call minutes or per delivered kWh of electricity. Due to the

[5] An additional issue, magnifying the problem, is the lack of transparency: Often the calling customer does not know that he is paying a higher price. Similarly, the subscriber may not be aware that people, who calls him, pays a higher price. If call-termination charges are allowed to differ substantially, regulators should increase transparency by imposing a requirement to inform callers (on a per-call basis) as well as subscribers of increased call charges.

[6] I originally pointed out this access-monopoly argument in a "debate article" in Berlingske Tidende October 20, 1999 (available at http://home.worldonline.dk/~holmside/Sonofon.htm). Two weeks later the question was raised in the news programme, "Pengemagasinet", where among others the director of Sonofon was interviewed. When asked about the high call-termination charge, he informed the interviewer that Sonofon had made "a mistake", that this mistake had been "corrected" the same day of the programme and that the price for call termination was now in line with the other operators. By some this would be seen as an indication that competition actually worked. This would be incorrect, though. Sonofon's decision was simply made by weighing the bad publicity, associated with the high call-termination charge, against the increased (direct) revenue - the decision was not forced by competitive pressure. In a competitive market, consumers who receive many calls would still benefit from subscribing to Sonofon since

magnitude of connection costs, many operators have chosen, or rather been required by regulators, to subsidise connection via the price of transport. This is illustrated in figure 2.2:

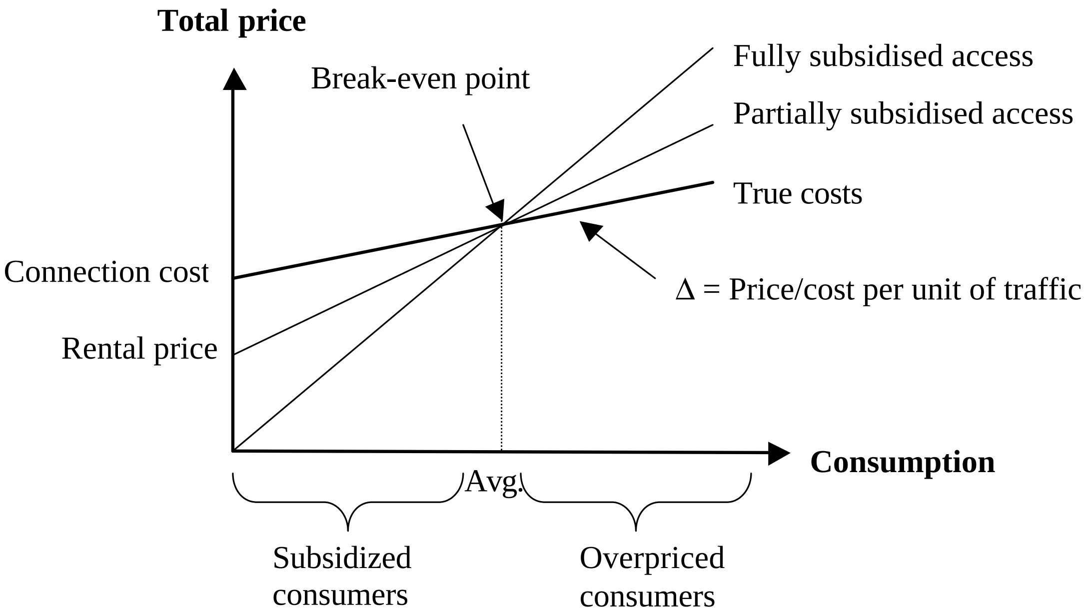

Figure 2.2 - Subsidised access

When the rental price is set below the cost of connection, the operator will need to charge a price above marginal cost on traffic in order to break even. If there is no competition, the operator or the regulator can choose between different two-part tariffs more or less freely as illustrated in figure 2.2 as long as consumers on average are paying enough to cover costs. As the figure shows, a combination of low rental prices and high traffic prices effectively subsidise low-usage consumers at the expense of high-usage consumers. Because low-usage consumers usually (but not always) are low-income consumers, regulators have typically imposed such a subsidising scheme on the former network monopolies for equity reasons. In the extreme case there is no charge for connection. Costs are financed entirely via the transport price. In the city of Copenhagen e.g., there is no rental charge for electricity. The entire price is charged per kWh[7].

Sonofon could offer low call prices, in "exchange" for high call-termination prices, which are not paid by the subscriber but instead by the calling party.

[7] This is true for all consumers receiving their electricity from Københavns Energi. In almost any other part of the country the price is divided into a fixed rental price and a price per kWh.

Cross-subsidies may also be the result of a political requirement for *geographically averaged prices*, which are widely used in many different network industries. Despite the fact that connection costs and/or transport costs typically vary from area to area, e.g. from rural areas to urban areas, prices are usually the same. If prices on average should cover costs, prices have to be set above costs in low-cost (urban) areas and below costs in high-cost (rural) areas.

Subsidy-schemes like those described above are perfectly viable under monopoly. But when competition is introduced, the schemes come under pressure because competitors can target profitable consumers - consumers with a relatively high consumption or consumers situated in low-cost (urban) areas - and offer them lower prices because of the lower average costs associated with servicing these customers. This is known as *cream-skimming*. There are two fundamental problems associated with entry based on cream-skimming. First, it undermines the subsidy scheme set in place by regulators for equity reasons[8]. Second, it may lead to inefficient entry and bypass of the incumbent's network if competitors with higher costs than the incumbent are able to enter only because of the possibility to exploit these cross-subsidies through arbitrage. By forcing down prices towards marginal costs for high-volume or urban consumers, allocative efficiency is increased; but it may be at the expense of productive efficiency. If entrants are more cost efficient than the incumbent is, productive efficiency is increased as well.

Entry by competitors, targeting only the profitable consumers, leaves the incumbent with all the unprofitable cross-subsidised consumers. The incumbent is thus left with an *access deficit,* defined by the difference between the cost of providing access and the revenue from providing access to these consumers. These access deficits have earlier been covered through prices which were set above (marginal) costs on the now competitive segment. In the chapters 4 and 5 it will be discussed how this access deficit may enter into the considerations of regulators when they determine the appropriate access prices. If entrants can not bypass the access network of the incumbent, one way to cover the access deficit is through the access price[9].

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[8] Cross-subsidies will always be a second-best way to redistribute income. If demand elasticities are estimated to be very low, however, and if usage is indeed proportionate to income, cross-subsidies might theoretically distort production and consumption incentives less than traditional ways of redistribution such as e.g. tax on labour. However, demand is typically not sufficiently inelastic for this to be the case in practice, and usage is not proportionate to income.

[9] With regard to electricity distribution in Copenhagen for instance, competitors will have to pay a distribution price to a distribution company, which incorporates the fixed-cost component and distributes it on a per-kWh basis. The incumbent, Københavns Energi, may therefore be able to maintain its current pricing policy with no rental charge.

2.2.2 Eliminating the access deficit through tariff-rebalancing

The obvious way to eliminate the access-deficit problem is to rebalance tariffs so that they reflect costs. In addition to eliminating the incumbent's access deficit, tariff rebalancing also increases allocative efficiency because consumers then face the same cost structure as society. Thus, there are strong incentives for the regulator as well as for the incumbent to rebalance tariffs. The largest obstacle to full tariff rebalancing is likely to be political unwillingness. Politicians think of their voters and, as explained above, tariff rebalancing typically benefits high-usage consumers (typically high-income consumers) at the expense of low-usage consumers (typically low-income consumers). For equality reasons - or maybe for vote-maximising reasons - politicians therefore tend to oppose tariff rebalancing. However, it is possible to combine rate rebalancing with low-user schemes. Low-user schemes have a modest rental fee. In turn, traffic prices increase rapidly after a certain limit. Self-selection then ensures that these allocative-distorting prices are reduced to cover only a limited amount of low-usage consumers. Such low-user schemes have paved the way for at least partial tariff rebalancing in telecom in the EU.

As noted by Laffont & Tirole (1996), access deficits may be hard to eradicate completely. A full rebalancing of tariffs may be hard to achieve. First of all, the elasticity of demand for subscription may not be negligible. If consumers were to pay the entire cost of connection, they might choose not to be connected. Customers might choose not to have a phone or they might choose an alternative such as a mobile phone. Ideally, the operator should also take into account the positive network externalities on other users when a customer is connected as well as the total revenue that would be lost if the customer were to disconnect. This foregone revenue covers both the profit made on terminating calls to the customer at hand and the profit earned by other operators for originating these calls. Secondly, bringing optic fibre or an electricity cable into a remote village may have some features of a public good, so that efficient pricing is unlikely to cover the corresponding fixed costs. Finally, as noted earlier, political restraints may exist, preventing the operator from eliminating the access deficit through a full rebalancing of tariffs. In particular a geographical de-averaging of prices in order to reflect costs is e.g. likely to meet strong political/public resistance[10].

[10] For more on geographical averaging and de-averaging, see chapters 4 and 8.

Chapter 3:

Essential facilities and the basic access-pricing problem

This chapter introduces and discusses the concept of an *essential facility*. The view of the European Commission and the European Court of Justice on the application of competition law to the access problem will also be investigated. A main purpose of the legal analysis is to investigate whether access to networks can be required based on competition law alone Finally, it is discussed how the access problem is affected by increased (network) competition.

3.1 What is an essential facility?

In 1992 the European Commission for the first time explicitly articulated an essential facility theory (Kallaugher & Völcker, 1998)[11]. It was in *Sea Container v. Stena Sealink*[12], where an essential facility was defined as "*a facility or infrastructure without access to which competitors cannot provide services to their customers*"[13]. The Commission found that Stena Sealink, which owned some port facilities used for ferry services to Ireland, had declined to provide access to those facilities on a non-discriminatory basis to a rival, who wished to operate an innovative service to Ireland using high-speed catamarans[14]. It stated that an "undertaking which occupies a dominant position in the provision of an essential facility and itself uses that facility [..] and which refuses other companies access to that facility without objective justification or grants access to competitors only on terms less favourable than those which it gives to its own services, infringes Article 86 [now 82][15], if the other conditions for applying that Article are met"[16].

It is important to note that "cannot provide" implies that the facility is not economically replicable by competitors. Thus, it is typically characterised by large economies of scale. Moreover, we should note that we are dealing with two different markets: an upstream market

[11] Earlier decisions may *implicitly* have been based on an essential facilities analysis.
[12] Commission Decision 94/19. O.J. No. L 15, January 18, 1994.
[13] Id. point 66.
[14] Another important and similar decision was *Port of Rødby*, Commission Decision 94/110, O.J. No. L55, 26.02.94
[15] With the Amsterdam treaty Article 86, concerning abuse of a dominant position, switched numbering to article 82.
[16] Point 66 (quoted from Kallaugher & Völcker, 1998)

and a downstream market. The essential facility is located upstream and is necessary to the production process in the downstream market. In the case described above, the upstream market is the port(s) and the downstream market is ferry transport. There are large economies of scale in port provision but not in ferry transport. An incumbent ferry operator, who also owns the port, has a natural incentive to deny competitors access to the port, in order to keep his monopoly on ferry transport[17]. In a sense the incumbent is expanding his dominant position in the upstream market into the downstream market. Under US law this is termed "monopoly leveraging".

3.2 Essential facilities in network industries

Network industries provide excellent examples of such essential facilities. In some industries like railways, electricity and gas the entire network is often considered an essential facility due to the economic characteristics described in chapter 2**.** Few would argue that two sets of parallel railway-networks are economically viable: It would imply an inefficient duplication of costs and the negative externalities associated with construction and operation are substantial. When a network constitutes an essential facility, then the operation of it is a natural monopoly.

It is less obvious that railway *transport* should be characterised by large economies of scale. In theory it is perfectly possible to have multiple operators, thereby introducing competition into the industry[18]. Following EU Directives[19], Denmark therefore decided to divest its old Railway company, DSB, into two companies as of January 1, 1998: Banestyrelsen, responsible for operation of the network, and DSB, responsible for operation of the trains. The Directives do not require legal/structural separation, only accounting separation[20].

[17] Ferry companies will typically refer to safety issues or lack of capacity.
[18] Practice, however, has indicated several problems concerning the co-ordination of traffic.
[19] Council Directive 95/19, and Council Directive 91/440.
[20] Under accounting separation the two divisions remain integrated as one legal entity, but the undertaking keeps separate accounts for the network. In theory (or according to proponents of accounting separation) it is then possible to ensure that the network division is not charging higher prices to competitors than it is to its own subsidiary. The incentive to favour the subsidiary, however, remains since the two divisions have the same owners. In practice the integrated firm can set high access prices to the subsidiary equal to those levied on competitors, while in practice the subsidiary acts as if the access price were lower. This will give the firm a comparative advantage similar to that obtained with discriminating access prices since the overall profit remains the same (part of the profit has just been shifted from the subsidiary to the network firm). To avoid this indirect cross-subsidy, the network needs to be "ring-fenced" from the competitive parts, costs need to be verifiable and the profit of the network (the "bottleneck facility") needs to be regulated in some way. The only way to entirely eliminate the incentive to cross-subsidise subsidiaries, is to require structural/legal separation of the divisions along with separate ownership.

A similar line of reasoning has been applied to the electricity industry, also following an EU Directive[21]. Transmission and distribution networks are characterised by large economies of scale and duplication of them would be inefficient. In production as well as trade, scale economies are much smaller (among other things due to new production technology) and competition in those markets can therefore be introduced. In May 1999 a reform including separation of production, transmission, distribution, and trade was passed[22]. Access prices to the transmission network are regulated on a cost-plus basis[23], while access prices to the distribution network are subject to income-cap regulation based on benchmarking[24].

The gas sector has not yet been liberalised, but an EU-Directive[25] has been passed and the Danish gas sector is about to be gradually liberalised as well.

The telecommunications sector, on the contrary, has been fully liberalised as of 1 January 1998 (at least on paper) without requiring structural separation. The reason for not separating out the (access) network is that the economies of scope between network operation and end-user service provision are much larger than they are in the other network industries. Also the major part of the product is transport itself as opposed to electricity and gas. Thus, it would make little sense to separate out the network and subject it to cost-plus regulation e.g.

This integration provides a lot more complexity to the problem of access pricing than under structural separation. This thesis investigates the access-pricing problem in a framework where the regulated firm is integrated, producing upstream as well as downstream.

An integrated operator has a second (strategic) incentive to charge high access prices in addition to the monopolist's traditional incentive to charge a monopoly mark-up: When an integrated operator raises the price of access to his network or essential facility, not only does he gain higher access revenues, he also increases the cost of rivals with whom he is competing in the downstream (retail) market. Thus, a higher access price may also increase the operator's revenue from the downstream market.

Another important feature of the telecom industry is the rapidly changing technology, redefining the economics of the industry. Originally, the entire network was considered to be a

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[21] EU Council Directive 96/92 of December 19, 1996 about gradual liberalisation of the electricity sector.
[22] Lov om elforsyning (L 234), accepted by Parliament May 28, 1999
[23] Or "rate of return regulation" - In Danish "Hvile-i-sig-selv-regulering". Elaborated in chapter 5, section 5.2.1
[24] For more information on the Danish electricity-sector reform, in particular the regulation of the distribution companies, see e.g. Holm (1999) http://home.worldonline.dk/~holmside/Papers.htm
[25] Directive 98/30 - The internal market for Gas Directive - 22 June 1998

natural monopoly, which were best operated by a single regulated company per region. But with the rapidly decreasing cost of fibre, switches etc. and the increased traffic, the economics have changed, and today only the local loop[26] is considered to be an essential facility - often termed a *bottleneck-facility*. This view is supported by the fact that entrants have invested heavily in their own core networks but have not yet invested in their own access networks[27].

Whether the local loop constitutes an essential facility has (not surprisingly) been questioned by incumbents, who are trying to avoid the obligation to offer competitors access to the local loop. They argue that substitutes such as mobile phones and CATV already exist. However, cellular phones do not yet offer similar capabilities for transferring data, the voice quality is not yet as good as it is for fixed phones and the price is higher. CATV-modems for data traffic exist but they are very expensive and still require a phone line to obtain two-way traffic.

If indeed the local loop is a bottleneck facility, competitors require access to it in order to compete with the incumbent. Such access can be provided in different ways. In Denmark politicians have required the incumbent, Tele Danmark, to unbundle its local loops, so that competitors can rent them and connect them directly to their own network. We return to the question of local loop unbundling in chapter 8.

Other examples of network industries are postal service and water. Substantial economies of density are present in postal delivery and postal collection. Thus, when liberalising the postal sector, entrants will need access to the distribution network as well as to the collection network. In water distribution, the entire distribution network constitutes an essential facility.

3.3 EU legal framework for requiring access to essential facilities - the essential facilities doctrine

Before moving on to an economic analysis of how to regulate the price of access in chapter 4 and 5, it is appropriate first to evaluate the legal framework for requiring access to essential facilities - the essential facilities doctrine. The latter constitutes the background for many of the decisions

[26] The local loop is the line - typically a copper line - connecting each subscriber to the local switch.
[27] Another reason, some might argue, is that the regulated price of access to the loops is so low that it biases the rent/build decision in favour of renting loops. Following the upcoming licensing of spectrum for Fixed Wireless Access (FWA), substantial investment in access networks can be expected.

about whether to give competitors access or not, and it needs to be considered by EU regulators when addressing the issue of whether or not to require local loop unbundling.

It is also interesting to consider whether entrants, based alone on existing EU competition, can require access to an incumbent's network and local loops. This legal question is very delicate and it is the subject of intense current debate among legal experts. The thesis does not try to draw any firm conclusions. It points out the key arguments made so far by the European Court of Justice in its relevant decisions and identifies the key questions, that the Court will have to take into consideration in future cases concerning requests for access, say to unbundled local loops.

As mentioned at the outset of this chapter, an essential facility argument was invoked for the first time by the Commission in its decision to require Stena Sealink to grant Sea Container access to its port facilities. The European Court of Justice (ECJ) has only recently referred explicitly to the doctrine in its jurisprudence. That was in the *Oscar Bronner* case, discussed below. However, the ECJ has in the past given judgement in a number of cases concerning refusal to supply - or refusal to give access[28]. In the most recent of these judgements, *Magill,* the ECJ ruled that the refusal by a television broadcaster to supply the weekly broadcasting list to a company, wishing to publish a comprehensive weekly television guide, constituted an abuse of a dominant position. However, the court also recognised that, as a rule, even dominant firms are under no obligation to license rivals to use their intellectual property. According to the court, such an obligation can arise only in exceptional circumstances. The ECJ also noted that exceptional circumstances applied in the *Magill* case because: (i) the license was necessary to allow sale of a new product; (ii) there were no justification inherent in the nature of the product that would justify a refusal to license; and (iii) the broadcasters were attempting to reserve the market where the licensed material was required to themselves[29].

But it was not until the *Oscar Bronner* case[30] that the ECJ for the first time explicitly referred to the essential facility doctrine. In this case the Austrian competition court asked the ECJ, whether a dominant newspaper's refusal to give a rival access to its distribution network constituted an abuse of a dominant position under Article 82 of the European Treaty. The case involved a company, Mediaprint, which publishes the two Austrian Newspapers *Kurier* and *Neue*

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[28] See e.g. *Commercial Solvents v. Commission* (Joint cases 6 &7/73), *Telemarketing* v. CLT (Case 311/84) and *Magill (RTE and ITP v. Commission)* (Joint cases C-241 & 242/91P). (referred in Kallaugher & Völcker, 1998)
[29] Kallaugher & Völcker (1998) referring to joint case C-241 & 242/91P at 824-25.

Kronen Zeitung with a combined market share of 46.8% in 1994. For the distribution of its newspapers, Mediaprint has established a nation-wide home-delivery scheme, delivering the newspapers directly to subscribers in the early hours of the morning.

The rival Oscar Bronner edits, publishes, manufactures and distributes the daily newspaper *Der Standard*. In 1994, that newspaper's share of the Austrian daily newspaper market was 3.6%.

In the main proceedings Oscar Bronner sought an order requiring Mediaprint to cease abusing its alleged dominant position on the market by including *Der Standard* in its home-delivery service against payment of reasonable remuneration. In support of its claim, Oscar Bronner argued that postal delivery, which generally does not take place until the late morning, did not represent an equivalent alternative to home-delivery.

In his opinion, General Advocate Jacobs concluded:

> "*It seems to me that intervention of that kind,* [requiring a dominant undertaking to supply the product or service or allow access to the facility] *whether understood as an application of the essential facilities doctrine or, more traditionally, as a response to a refusal to supply goods or services, can be justified in terms of competition policy only in cases in which the dominant undertaking has a genuine stranglehold on the related market. That might be the case for example where duplication of the facility is impossible or extremely difficult owing to physical, geographical or legal constraints or is highly undesirable for reasons of public policy. It is not sufficient that the undertaking's control over a facility should give it a competitive advantage*."[31]

We see that duplication of the facility has to be *impossible or extremely difficult*. In the following judgement, the ECJ also ruled that the refusal by Mediaprint to allow Oscar Bronner access to its distribution network did *not* constitute abuse of a dominant position within the meaning of Article 82 of the European Treaty.

The ECJ inter alia argued that "*other methods of distribution such as by post and through sale in shops and at kiosk [..] exist*"[32]. Thus, substitutes for the essential facility exist. Furthermore, "*it does not appear that there are any technical, legal or even economic obstacles capable of making it impossible, or even unreasonably difficult, for any other publisher of daily*

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[30] Case C-7/97, Oscar Bronner GmbH & Co. KG v Mediaprint Zeitungs- und Zeitschriftenverlag GmbH & Co. KG and others.
[31] Opinion in Case C-7/97 at point 65.
[32] Case C-7/97 at point 43.

newspapers to establish, alone or in co-operation with other publishers, its own nation-wide home-delivery scheme and use it to distribute its own daily newspapers."[33].

And very importantly, the ECJ emphasises that "it is not enough to argue that it is not economically viable by reason of the small circulation of the daily newspaper or newspapers to be distributed."[34]. And continues *"For such access to be capable of being regarded as indispensable, it would be necessary at the very least to establish, as the Advocate General has pointed out at point 68 of his Opinion, that it is not economically viable to create a second home-delivery scheme for the distribution of daily newspapers with a circulation comparable to that of the daily newspapers distributed by the existing scheme."*[35]

The latter has important consequences for the application of the essential facility doctrine. Complainants, requiring access to an essential facility, will typically be smaller undertakings. But as indicated in the last quotation, the ECJ considers the relevant comparative indicator to be a competitor with a size, similar to that of the holder of the essential facility!

If we apply this argument to a hypothetical case, involving a refusal of providing access to the local loop in telecom, it would seem that a future complainant would have to show that even if he had the size of the incumbent operator, it would not be reasonable to establish neither his own access network, nor one in co-operation with competitors. This appears to be a rather strict definition of an essential facility, which is why the essential facility doctrine seems unlikely to be applicable for telecom networks, where an entrant's main problem is the substantial economies of density, explained in chapter 2. In this respect, it would also have to be considered to which degree a network could be established using substituting technologies such as wireless local loops. It is worth remembering, as mentioned above, that Advocate General Jacobs explicitly pointed out that "[*i*]*t is not sufficient that the undertaking's control over a facility should give it a competitive advantage"*. Thus, even though it is economically disadvantageous to construct a competing access network, the *Bronner* case suggests that it would be difficult to gain access to local loops on the basis of EU competition law and the essential facility doctrine alone[36].

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[33] Id. at point 44.
[34] Id. at point 45.
[35] Id. at point 46.
[36] This opinion is supported by OVUM (1999)

On the basis of the above, in particular the *Oscar Bronner* case, one can conclude that the following conditions must be fulfilled for a facility to be essential under Article 82[37]:

1. The dominant firm is dominant in the provision of a service linked to a "facility".
2. Refusal of access to the facility is likely to eliminate competition in the downstream market.
3. The service is indispensable for the applicant's business, which means that there must be no possibility of substitution.
4. Duplication of the facility is "*impossible or unreasonably difficult*", typically due to technical, legal or economic constraints.
5. When determining the economic constraints, the relevant comparative indicator is a competitor of the same size as the holder of the facility.

This seems a somewhat more restrictive definition of an essential facility than is found in the US.

When the essential facility is determined to be essential, the dominant firm must act as an *independent operator* would act (Kallaugher & Völcker, 1998 and OVUM, 1999):

1. The dominant firm may only refuse access where an independent operator would refuse access under similar conditions. Thus, refusal needs to be motivated by objective reasons such as e.g. technological constraints or limited capacity.
2. The dominant firm has an affirmative duty to consult with the customer in order to deal with problems of access to the facility.
3. The dominant firm's duty not to discriminate goes beyond the requirement not to treat similarly situated customers differently - as in Article 82(c) - but requires fair and proportionate treatment of all customers[38].

[37] This version of the essential facility doctrine is based on an analysis of Kallaugher & Völcker (1998), the Bronner case and the "Access Notice" of the European Commission (1998). Commission (1998): "Notice on the Application of the Competition Rules to Access Agreements in the Telecommunications Sector", 31 March 1998. http://www.ispo.cec.be/infosoc/telecompolicy/en/ojc265-98en.html. Kallaugher & Völcker was written previous to the final *Oscar Bronner* judgement.

[38] In the Oscar Bronner case, the complainant, Oscar Bronner, also argued that Mediaprint had discriminated against it by including another daily newspaper, *Wirtschaftsblatt*, in its home-delivery scheme, even though *Wirtschaftsblat* is not published by Mediaprint. Mediaprint contested this argument of discrimination by pointing out that the position of *Wirtschaftsblatt* was not comparable to that of *Der Standard*, since the publisher of the former also entrusted Mediaprint with printing and the whole of distribution, including sale in kiosks, so that home-delivery constituted only part of a package of services. Because the ECJ decided that the distribution network was not an essential facility, it did not have to consider this argument, which falls under the independent operator requirement (see judgement point 48 and 49).

On the basis of the ECJ's rather strict definition of an essential facility, EU competition law alone appears to be inadequate for establishing true and viable competition in network industries. Thus, when introducing competition into network industry there is a need for a sector-specific regulation. And indeed we have seen such regulation applied in telecom, gas and electricity with one of the key points being the requirement of third-party access or structural separation.

3.4 Two-way networks, network competition and collusion

So far, the access problem has been presented in a situation with only one access network. This section considers whether the introduction of competing access networks removes the need to regulate access/interconnection prices. This is interesting to in telecom where competing access networks will be constructed in the near future using alternative technologies such as e.g. Fixed Wireless Access (FWA). The section also explains how a problem of double marginalisation may arise when two networks, with each their access network, interconnect.

3.4.1 Two-way networks and the double-marginalisation problem

In a telecom network, "traffic" runs in both directions, hence the term *two-way network*. Completion of a call requires access to two local loops - two bottlenecks. If these bottlenecks belong to two separate networks, the well-known problem of double marginalisation may arise in an unregulated framework: The two networks will each charge a mark-up on their costs of providing access because they hold a monopoly over access to their subscribers[39]. It is this "mark-upped" price that the networks face as the cost of terminating a call on the other network. When in turn they set the price to consumers, they apply the mark-up to this cost and not the actual cost - the cost to society - hence the term: *double marginalisation*. This is detrimental to welfare because of the increased gap between prices and costs. As Tirole (1988) notes: "What is worse than a monopoly? A chain of monopolies." The problem is equivalent to the classical double-marginalisation problem with a manufacturer and a retailer. When a call is made from network A to network B, A is the retailer of call termination and B the manufacturer.

Not only is double marginalisation detrimental to welfare, it also reduces overall profits to the networks. The reason is that the retailer (the originating network) does not take into account the profit of the manufacturer (the terminating network) when setting the retail price and vice versa. Thus, "vertical externalities" exist. "Vertical integration" (thinking of it as a retailer and a manufacturer[40]) would remove double marginalisation through an internalisation of these externalities, benefiting consumers through lower retail prices and networks through increased traffic, generating higher revenue despite the lower retail prices[41]. Absent retail competition and the accompanying strategic incentives to set high access charges, the two networks should be able to alleviate some, if not all, of the problem through a mutual lowering of the access price. This raises the question of what happens when networks start competing over subscribers.

3.4.2 Network competition and the incentive to collude

It should be obvious that regulation of access prices is necessary when one operator holds a monopoly over access. The natural question to ask then is whether such regulation could be withdrawn in an industry with competing (access) networks. This question is becoming increasingly relevant for regulators in telecom where networks are being rolled out - networks, which sometime in the future may include access networks as well. Laffont, Rey, and Tirole (1998a,b) and Armstrong (1998b) have investigated such an access-pricing problem with *network competition*. They demonstrate that operators may continue to set high access prices because the access price can be an instrument of collusion to reduce competition in the retail market. Thus, regulation of access (interconnection) prices is also required in a world with competing networks.

Laffont, Rey, and Tirole (1998a,b) develop a conceptual framework for analysing a model of unregulated competition between interconnected networks. They present two frameworks. One where the interconnected networks can not discriminate between the price they charge for calls terminated on their own network and calls terminated on the rival network (1998a), and a second where such discrimination is possible (1998b). The scholars investigate the problem under an assumption of linear prices as well as an assumption of non-linear prices (two-part tariffs). In their models, networks are horizontally differentiated (Hotelling) as they offer different functionalities that appeal to different consumers. The scholars make two key assumptions:

[39] Here we consider a set-up where firms are not competing in the retail market. In the next section a framework with competition in the retail market will be introduced.
[40] Talking about two networks, "horizontal integration" (merger) might seem to be a more correct term. However, with regard to the double-marginalisation problem, it is most appropriately thought of as vertical integration.
[41] For a simple algebraic example of the double-marginalisation problem and the effect on prices, quantity, profit and welfare see Tirole (1988), who considers the traditional double-marginalisation problem.

1. *Balanced calling pattern,* which implies that in the case of equal marginal (retail) prices; flows in an out of a network are balanced, even if market shares are not. This is true if every consumer has an equal chance of calling an arbitrarily chosen consumer, belonging to his own network, and another arbitrarily chosen consumer, belonging to the rival network[42].

2. *Reciprocal access pricing,* which means that a network pays as much for terminating a call on the rival network as it receives for terminating a call originated on the rival network[43]. A regulatory requirement for reciprocity prevents a dominant network operator, typically the former monopolist, from (ab)using his dominant position to obtain an agreement under which he pays substantially less for having calls terminated on the smaller network than he himself charges the small network operator for the same service. Laffont, Rey, and Tirole note that "regulators and antitrust authorities are likely in the future to insist on the reciprocity of access chargers". Surprisingly few countries have adopted such a principle of reciprocity. Denmark e.g. has not[44].

The introduction of competition over customers put a downward pressure on the retail price - or more precisely the retail mark-up - thereby alleviating some of the problem of double marginalisation. By attracting a customer from a rival network, the network not only gains the call revenue from this subscriber, it also avoids paying access charges when other subscribers call this customer. One might therefore even imagine the mark-up competed down below zero. However, competition also introduces the earlier described strategic incentive to raise access prices in order to raise the rivals cost.

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[42] In this case, the fraction of calls, originated on a network and terminated on the same network, is equal to the fraction of the total number of consumers belonging to that network. Subscribers to a small network are more likely to call a subscriber on the large network than subscribers on the large network are to make a call to the small network. However, there are more subscribers on the big network and the flow of calls between the two networks therefore balances (for equal marginal call prices).

[43] Laffont, Rey, and Tirole assume termination costs to be identical. More generally, reciprocity means that the difference between access prices reflects only the differences on the cost of giving access. It is e.g. much more costly to terminate a call on a mobile network than it is on a fixed network. An interconnection agreement between a mobile network and a fixed network with equal access charges would *not* be reciprocal but strongly discriminatory.

[44] In Denmark most of the agreements made by the industry have led to reciprocal access charges. However, as mentioned earlier, one of the operators, Sonofon, decided to double its charges compared to the charges it paid to the other operators. A few weeks later, however, it decided to reverse its decision. Officially, because it had made a "mistake". The real explanation of course, was that the incumbents, Tele Denmark, quite naturally had decided to - and been allowed to - pass these charges on to their customers, when they called Sonofon customers. These heavily increased prices had given rise to a public debate, and Sonofon simply weighed the benefits from increased access revenues against the potentially bad publicity they would be getting. See also footnote 6.

Laffont, Rey, and Tirole demonstrate that starting from zero substitutability, a small increase in substitutability (and thus an increase in competition) has an ambiguous effect on the access charge but lowers the final price. [This is their proposition 4.]

The effect on the access price is ambiguous because, on the one hand, increased substitutability increases the gain from having a rival raise his retail price in response to increased (access) costs. On the other hand, the rival will be more reluctant to increase his retail price when substitutability is substantial. All other things equal, the latter effect reduces the incentive to jack up the access price.

Regarding the retail price, proposition 4 of Laffont, Rey and Tirole shows that even if the first effect dominates, it can not dominate the decrease in the retail mark-up. Thus, increased substitutability decreases retail prices, alleviating the double-marginalisation problem.

Laffont, Rey and Tirole also demonstrate that, as long as a symmetrical equilibrium exists, in which the two networks charge the same retail price, this retail price increases with the access charge[45]. Thus, the access charge can serve as a collusion device. [This is their proposition 2(i).]

To understand this, we consider the benefit of lowering the retail call price slightly. This has two effects: First, it attracts customers from the rival's network. Under a balanced calling pattern, though, this does not affect the *net* outflow. Second, the callers on the network will respond to the lower prices by calling more (assuming elastic demand). Thus, the outflow of calls increases, while the inflow does not - leaving the network with an access/interconnection deficit[46]. It may still pay to undercut the price since the retail price is higher than the access charge. But the point is that agreeing on a higher access price, paid for the net outflow, lowers the gain from undercutting the call price and thereby softens competition[47]. The regulatory implication of this is a continued need for regulation of access (call termination) charges - even in a future state of the world with multiple networks, competing vigorously over customers.

[45] Existence requires that access charges or the substitutability of the two networks are not too high. If they are, each network will have an incentive to undercut its rival to corner the market. A symmetrical equilibrium will fail to exist.
[46] Not to be confused with the access deficit associated with unbalanced tariffs described in chapter 2.
[47] This argument implicitly assumes that networks can not charge different prices for on-network and off-network calls. If such discrimination were possible - like e.g. we see it for mobile networks today - the reasoning would be invalidated since an undercutting network could choose only to lower the price for on-network calls - leaving the net outflow of calls unaffected. It would be outside the scope of the thesis to explore the implications of introducing this kind of price discrimination. Laffont, Rey and Tirole investigate this set-up in detail in their companion article (1998b). They conclude that networks *individually* gain from charging different prices for on- and off-network calls. But increasing each other's costs through high access charges need not raise industry prices and profitability because it leads to more intense competition for market share. They also show that price discrimination makes it very difficult to enter with less than a full-coverage network and that the regulator therefore should prohibit price discrimination.

Chapter 4

Regulating access to networks

Chapter 5 will discuss different proposed methods for establishing a proper access price. To be able to evaluate these different methods it is necessary first to establish the regulatory objectives. Before turning to these objectives, though, it is appropriate to consider the first question legislators have to answer when deciding on how to regulate network access. It is the question of whether to rely on general competition law or on sector-specific regulation. In telecom, academics and regulators are currently debating this question.

4.1 Sector-specific regulation versus general competition law

4.1.1 The competition-law approach

Under the competition law approach, questions are settled in the context of general competition law, in particular Article 82 (abuse of a dominant position) in conjunction with the developed case law, first of all the essential facility doctrine described in chapter 3. In each Member State, decisions will of course be based on the competition law of that state, but typically the latter will be very close to EU competition law. In any case, the products of network industries are increasingly being traded across borders. And in this case, EU competition law has priority to national competition law.

Insofar as it may affect the trade between Member States, Article 82 prohibits undertakings with a dominant position to abuse this position by:

(a) imposing unfair prices or other unfair trading conditions

(b) limiting production (refusing to supply)

(c) discriminating against other trading parties

(d) imposing supplementary obligations with no connection to the subject of the contract

In addition Article 81 (ex 85) prohibits agreements between undertakings, which may affect trade between Member States and which "have as their object or effect the prevention, restriction or distortion of competition within the common market".

Article 86 (ex 90) emphasises that the competition-law articles, including Articles 81 and 82, also apply to public undertakings; and to undertakings to which Member States have granted special or exclusive rights, which is the case for the former monopolistic operators in network industries.

Finally, Article 154 (ex 129b), which is not part of the competition law, complements Article 82 by explicitly requiring the Community to aim at "promoting the interconnection and inter-operability of national networks as well as access to such networks".[48]

A major advantage of relying on general competition law is that it increases regulatory certainty by relying on clear and general principles, which are likely to remain unchanged. Moreover, regulators do not ex ante have to specify detailed provisions, which are likely to distort welfare and reduce the flexibility of operators. Finally, the principles can be applied across sectors. In telecom, this is becoming increasingly important due to the increased *convergence* of industries such as fixed and mobile telecom, CATV, Internet, satellite etc. Due to digitalisation, services can be delivered over multiple types of infrastructure. If these industries are subjected to different sector-specific regulation, there is a risk that one infrastructure will be favoured over another. Not due to superior technology or economic features but simply due to biased regulation. This is of course highly problematic from a welfare point of view. The obvious way to ensure technology neutrality is increased reliance on general competition law[49], which also provides regulators and operators with more flexibility.

The main disadvantage of the competition law approach is that it does not allow the competition authority to impose specific solutions, which it finds to be appropriate. For instance it may be possible for a competition authority to rule that refusal of access constitutes an abuse of a dominant position. But it can not rule that it constitutes abuse of a dominant position for the next 5 years, at which point it becomes legal (the example is taken from Cave and Crowther, 1998). In Canada and Austria, for example, regulators have required access to unbundled local

[48] The articles are listed in full in Appendix A.
[49] For more on the regulatory implications of convergence see e.g. Clemens (1998), Commission (1997) Green Paper on convergence, and the Commission (1999): "Results of the Public Consultation on the Convergence Green Paper".

loops only for a limited period of 5 years in urban areas. Such a solution can only be chosen under sector-specific regulation.

Furthermore, when the market is characterised by having one dominant operator, as still is the case in most network industries in the EU, it is difficult under competition law alone to neutralise this operator's market dominance - or as it is often described metaphorically: to "level the playing field". The reason is that application of the very powerful Article 82 requires that the incumbent is actually abusing its market dominance. Under general competition law it is also impossible to enforce *asymmetric regulation*, which may sometimes be needed if entrants are to compete against the incumbent, who possesses a number of "inherited" advantages. Such authoritative flexibility requires the use of sector-specific regulation[50].

In New Zealand, legislators decided to rely on industry agreements about access (interconnection) in telecom. The incumbent, New Zealand Telecom, was only subject to general competition law when negotiating interconnection with the main rival, Clear Communications. As could be expected - at least with the wisdom of hindsight - it was almost impossible to obtain such an agreement and the liberalisation process was retarded. Mueller (1998) provides a thorough investigation of the New Zealand experience with interconnection and reliance on industry agreements and general competition law. He concludes that the New Zealand experiment was a failure and that it clearly indicates that competition policy alone is insufficient for regulating access when the incumbent has a very dominant position.

With regard to technical interfaces and the like, access agreements are, on the contrary, best left to the industry, that holds the technical expertise. But negotiation will have to be monitored to prevent the incumbent from abusing his dominant position to either delay access/interconnection or use it to impose unreasonable terms on entrants. Regarding the price, industry agreements have the advantage of allowing operators to use flexible and innovative pricing schemes such as e.g. two part tariffs/quantity discounts, peak-load pricing[51] etc. However, it will always be necessary to audit the resulting prices to ensure that they reflect costs. In this respect one should not forget that the incumbent not only holds a better bargaining position; he

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[50] Under Danish telecommunications law e.g., an operator with a market share above 80 % will only be allowed to recover 30 % of his operating costs while operators with market shares below 80% are allowed to recover 100 %. Comments on §55(2) of Bill L248 of 30 March 2000 on law about competition and consumer issues for telecommunications, http://www.fsk.dk/fsk/div/love/l248.doc

[51] Under peak load pricing, the firm charges higher prices in 'peak periods' when usage is high and capacity therefore scarce than it charges in 'off-peak periods', where usage is low and capacity therefore abundant.

usually also has superior information about costs and has more staff to lobby and lead the negotiations. One way of reducing the incumbent's incentive to abuse his dominance is to ensure that unrelated issues are negotiated separately, reducing the incumbents incentive to leverage a strong bargaining power in one area into another by linking the two issues together[52].

A final point to consider (noted by Kiessling & Blondeed, 1998) is the fact that antitrust authorities and courts not may be able to process the growing number of conflicts between incumbent operators and newcomers. If law suits can be expected it is preferable to avoid such lawsuits through clear regulatory rules.

4.1.2 Sector-specific regulation

Compared to a competition authority, a regulator can take a much broader view of the industry and of the regulatory objectives and then design specific solutions for each problem. As mentioned in the previous section, such flexibility may be especially needed in the initial liberalisation phase, when competition is emerging and asymmetrical regulation is called for. The reverse of the medal is the regulatory uncertainty, arising from the regulator's discretionary powers. Under sector-specific regulation it is therefore important to try and stick to some pre-specified rules and principles. As mentioned earlier, sector-specific regulation also risks biasing the choice between different technologies, often unintentionally.

Another problem with sector-specific regulation is the risk of *regulatory capture*. On the one hand, civil servants need to acquire important industry-specific knowledge in order to improve the quality of their decisions. On the other hand, the consequence of this is that their main alternative employment is in the industry that they regulate. As pointed out by Bergman, Doyle, Neven and Roller (1998) among others, civil servants may therefore have an incentive to accommodate the firms that they regulate in order to ensure adequate future job opportunities.

In the EU, network industries are primarily subject to sector-specific regulation based on EU Directives implemented into national legislation, which is then administered by National Regulatory Authorities, NRAs. In telecom, for instance, a number of Commission Directives on

[52] Such conduct is indeed illegal according to Article 82(d) EC, stating that abuse of a dominant position may consist in "making the conclusion of contracts subject to acceptance by the other parties of supplementary obligations which, by their nature or according to commercial usage, have no connection with the subject of such contracts".

interconnection, universal service, leased lines, and licensing inter alia, have been passed along with a number of more specific recommendations and studies[53].

4.1.3 Transition from sector-specific regulation towards general competition law

As should be clear from the above, the benefits from sector-specific regulation are largest in the early phases of the liberalisation process, whereas the benefits of relying on general competition law are largest in the more mature phase of liberalisation. And vice versa for the disadvantages. Therefore, sector-specific regulation is needed initially to neutralise network dominance but should gradually be substituted by increased reliance on general competition law when competition over the relevant service or infrastructure provision has evolved. When an industry is liberalised or 'deregulated' the regulatory tasks may actually increase in the initial phase because of the need to regulate wholesale markets and promote entry[54].

As competition evolves, however, the regulatory tasks should decrease due to the possibility of increased reliance on industry negotiations subject only to general competition law. This is illustrated in figure 4.1, adapted from Bergman, Doyle, Neven and Roller (1998):

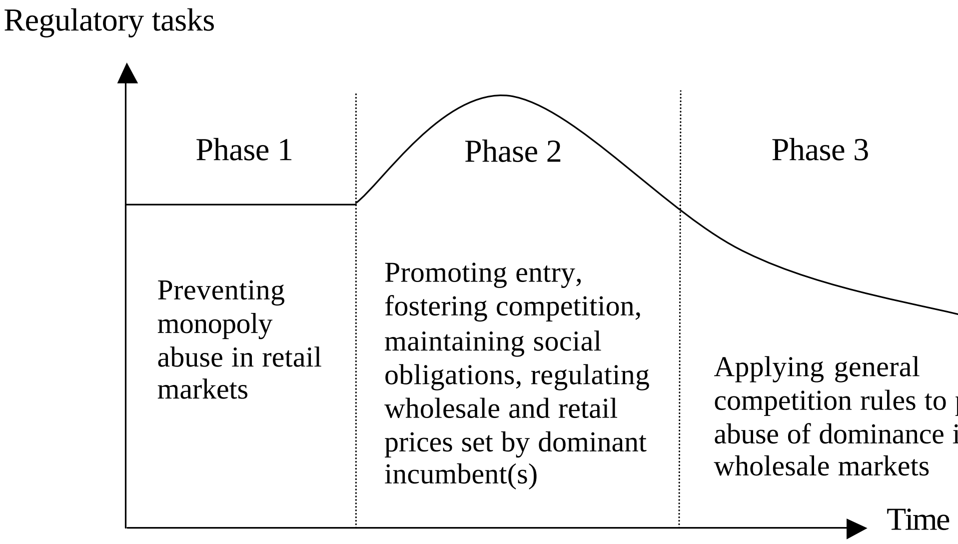

Figure 4.1 The three phases of regulatory activity

[53] For a recent overview of these Directives and the status of their transposition into national legislation in the Member States, see the 5th implementation report from the Commission of November 1999. See also section 5.7.
[54] For this reason, the liberalisation process has often sarcastically been termed "re-regulation" instead of deregulation.

Whether it is chosen to rely on competition law or on sector-specific regulation for regulating access, it will be necessary to decide what constitutes an appropriate access price. This theme will be the focus of the remaining part of the thesis. In order to evaluate different pricing principles it is necessary first to consider the regulatory objectives. This is the purpose of section 4.2

4.2 Regulatory objectives

4.2.1 (Static) allocative efficiency

Prices should reflect society's cost of production to ensure that scarce resources are allocated to their most valuable use. This requires that the marginal cost to consumers (the price) for using the network and for getting connected to the network equal the marginal costs of an efficient network operator, producing these services.

4.2.2 Productive efficiency

A given production should be produced at the lowest possible cost[55]. The incumbent should produce cost effectively; and inefficient entry, i.e. entry by rivals with higher cost than the incumbent, should be prevented.

4.2.3 (Dynamic) investment efficiency

Efficient, and only efficient, investments should be encouraged and undertaken. On the one hand, this requires that a network operator, facing a given efficient investment, can expect to cover the total opportunity costs associated with undertaking the investment. The access price therefore needs to be set sufficiently high. On the other hand, inefficient bypass, i.e. entrants investing in their own access networks even though it is much more costly to society than renting capacity from the incumbent, should be avoided. This requires that the access price is not set too high.

4.2.4 Equality, cross-subsidisation and universal service

As mentioned in chapter 2, legislators may want to cross-subsidies certain segments of consumers such as e.g. low-income consumers or rural (high-cost) consumers through prices, which are set below costs. This normally takes the form of a relatively low connection/rental fee to ensure that most consumers can afford being connected to the network and is financed via a relatively high usage price. An obligation to provide services at "affordable prices" is termed a Universal Service Obligation (USO) and is typically held by the old monopolies[56].

As explained in chapter 2, the introduction of competition and the possibility of cream-skimming undermines the system of financing the USO through cross-subsidies. If politicians are not willing to fully rebalance tariffs to costs, they will need to come up with a way of compensating the operator holding the obligation to serve the unprofitable customers. The cost of Universal Service can be funded either through a Universal Service Fund (USF) to which all operators contribute according to their market share, or through a supplement to the access charges of the Universal Service provider (the incumbent), often referred to as an *access-deficit charge*[57]. The latter solution, however, is strongly inferior to a USF because it creates inefficient incentives to avoid access/interconnection through bypass. It also violates market-neutrality requirements with regard to market players, services, technology and vertical structure as well as allocative efficiency, in particular if supplementary charges are based on usage, say, call minutes (WIK 1997). All operators, including of course the incumbent, should contribute to a USF whether or not they bypass the incumbent. An obvious way to achieve this is to make operators' contributions dependent on their total revenue. An additional benefit of establishing a USF is that it allows allocating the USO to the cheapest provider or group of providers.

When establishing these costs, one should not confuse the costs of universal service with the access deficit. The access deficit is simply the difference between the total costs of subscriber lines minus total rentals (subscriber fees) received from these lines. But many of these costly lines end up being profitable for the provider due to call revenues. Only when the total costs from serving a customer are larger than total revenue attributable to this consumer (including Internet access etc.) should the provider be compensated for this difference through a contribution from the USF. The Commission has therefore wisely required Universal Service costs to be calculated as *net* costs: The difference between the surplus of operating in a given area *without* a USO and operating in the same area *with* such a USO. In this way all the indirect benefits from holding a USO, such as corporate reputation, ubiquity/coverage, access to full-range usage data, advertising

[55] Or alternatively production should be maximized for a given amount of input/level of costs (society should "produce on the production curve"). Inefficient production is also known as *X-inefficiency*.

[56] In telecom, the USO also covers delivering phone service to disabled people at reasonable prices.

[57] As noted by Valletti (1999), one can in principle distinguish between an *access deficit*, due to unbalanced tariffs when rental an connection costs exceed the corresponding charges, and a *universal service deficit*, due to

effects of public payphones etc. are also taken into account. As noted by WIK (1997) the incumbent operator is actually more likely to benefit from the status of USO-provider than to actually incur a net cost. In Denmark, like in most other EU Member States, the incumbent, Tele Denmark, has also abstained from requiring compensation for its USO. Only two Member States (France and Italy) have put a Universal-Service-funding mechanism into operation and only in France has this actually resulted in payment transfers between operators[58]. In general, it should be a goal in itself to reduce the burden of the costs associated with the USO since these represent a transfer of wealth from entrants to the incumbent and therefore may serve as a barrier to entry[59].

It would be beyond the scope of this thesis to go into more detail with the costing and financing of the USO. But it is a key regulatory issue along with access pricing when opening up network industries to competition, network industries in which heavy cross-subsidising has taken place in the past[60]. The exact same line of reasoning applies in electricity, gas, post etc.

The social (equity) objective clearly conflicts with the three efficiency-objectives because it favours prices, which do not reflect the true costs to society. This gives rise to an inefficient over-consumption of the subsidised services - think only of local telephony or Internet dial-up in the US[61] - and under-consumption of the overpriced goods like was earlier the case for international telephony.

Furthermore, as mentioned above, unbalanced tariffs may cause inefficient entry. Thus, there are strong arguments in favour of rebalancing tariffs. Tariff-rebalancing, however, by definition works against the social objective because it increases the cost to low-usage consumers. An introduction of special low-user schemes with relatively low connection/rental fees and modest call prices for a limited amount of minutes reduces the problem substantially. To the extent that call prices increase rapidly beyond this limit, self-selection will ensure that these allocative-distorting prices are reduced to cover only a limited amount of consumers.

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geographically averaged tariffs and uneconomical subscribers. But without a detailed accounting system, these two types of deficits are difficult to separate.

[58] Commission (1999): 5th Report on Implementation of the Telecommunications Regulatory Package. 11 November 1999 http://www.ispo.cec.be/infosoc/telecompolicy/5threport.html

[59] An alternative to a USF financed by industry, could be one financed by general taxation based on the argument that the USO is imposed for reasons like equity and national coherence.

[60] For more on the scope of the Universal Service Obligation in telecommunications and the costing and financing of it, see Commission Communication(96) 73 on Universal Service and WIK (1997): "Costing and Financing Universal Service Obligations in a competitive Environment in the European Union".

[61] In the US local telephony is free. Consumers may therefore find it convenient to stay connected without actively using the Internet, ignoring the fact that this take up capacity at the switch.

As exemplified above, the described regulatory objectives may potentially conflict with each other. The regulator will therefore have to find the right balance between these objectives.

4.2.5 Additional regulatory objectives and arguments for encouraging entry

Entry by more cost-effective producers lowers production costs and forces the price of the incumbent toward costs. The former increases productive efficiency and the latter allocative efficiency. These are some of the key benefits from entry and competition.

However, there may be other benefits associated with entry and competition. For instance it provides the regulator (and the incumbent) with a *yardstick* for estimating cost and demand elasticities on the competitive segment. In case entrants offer a slightly differentiated product to that of the incumbent, entry also increases *diversity* for consumers. Even when the entrant is not more cost effective, diversity alone increases welfare. Increased competitive pressure on the incumbent is also likely to spur *innovation* - by the incumbent as well as by entrants. Finally competition also puts pressure on the incumbent to increase efficiency through cutting away excessive "fat" and probably makes it easier for management to gain accept for cost-reducing measures such as layoffs.

These additional benefits from competition, described above, are probably the reason why competition is often argued to be the goal in itself. However, it is worth emphasising that the introduction of competition, say through an access requirement, should always be a *mean* to obtain the regulatory objectives and not the *goal* in itself.

Chapter 5

Determining the access price

Having considered the different regulatory objectives in chapter 4, we are ready to evaluate different methods for determining the access price. The problem of regulating the price of a natural monopoly is introduced and the main problems associated with the first-best solution: marginal-cost pricing, are discussed. The chapter then reviews some overall approaches to regulation: cost-plus regulation, price-cap regulation and a price based on forward-looking. After this introduction, we turn to the core of the chapter: an evaluation of the most prominent proposals for regulating access prices. The chapter ends with a brief presentation of the EU legal framework for pricing access/interconnection in telecom and some non-price issues.

5.1 Regulating natural monopolies and the first-best solution: Marginal-cost pricing

Figure 5.1 serves to illustrate the economics of a natural monopoly and the problem of the first best solution: marginal-cost pricing.

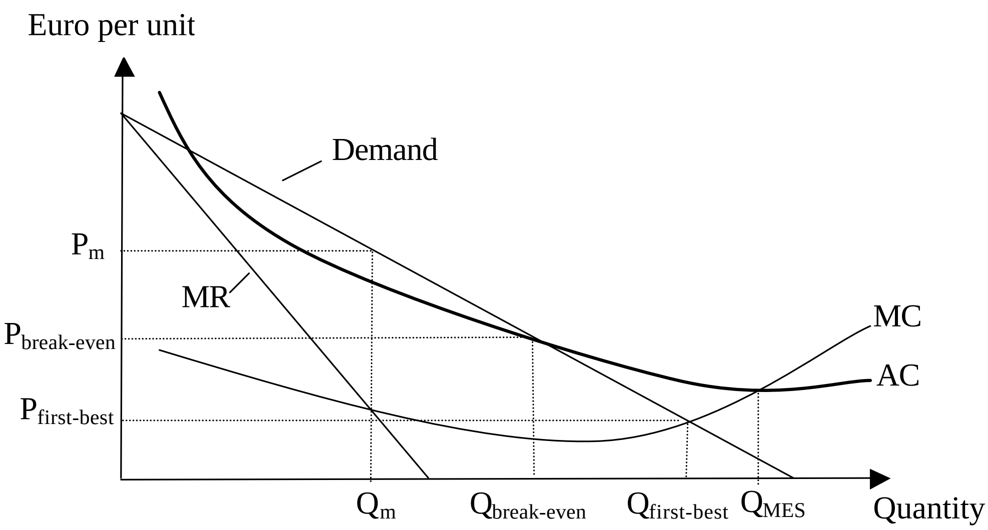

Figure 5.1 Natural monopoly

The firm holds a natural monopoly because average costs (AC) are falling in the relevant range. The minimum efficient scale (MES) is so large compared to demand that there is only room for one firm[62]. The shapes of the cost curves reflect some very large fixed costs, say of building an access network. On the contrary, marginal costs (MC) are relatively low. As soon as the access network has been established, it is not very expensive to transport an additional unit over the network[63]. As long as MC is below AC, AC is falling[64].

Now, if the firm was left unregulated, basic economic theory tells us that the firm would set MC = marginal revenue (MR) and produce a monopoly quantity of Q_m at the monopoly price P_m. The network operator would then earn a profit since $P_m > AC(Q_m)$.

From a welfare point of view, however, the price should be set equal to MC. Such a price sends the appropriate signals to consumers, about the cost to society of producing/consuming an extra unit of the access service[65]. To set the regulated price equal to MC is therefore known as the *first-best solution.*

The problem with this first-best solution, when dealing with a natural monopoly, is that it does not allow the operator to cover his (fixed) costs because P=MC<AC in the relevant range. No private operator would invest in network infrastructure if price were set equal to MC, unless he was compensated with state subsidies. Static allocative efficiency would be achieved at the expense of dynamic investment efficiency.

To implement the first-best solution, it is therefore necessary either to operate the network as a public enterprise or to subsidise a private operator. Public ownership of network operators has been widespread in most European network industries, and still is, even in telecom where privatisation is most advanced. In theory, public ownership may be just as effective as private ownership. In practice, however, privately owned firms tend to operate in a more cost-effective way and to be more innovative than publicly owned firms are[66]. Compared to a public firm, a

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[62] Implicitly assuming that entrants face a similar cost structure.
[63] In telecom e.g. MC are close to zero.
[64] In the figure MC is U-shaped. A U-shape could illustrate that operation costs per unit initially are falling due to the presence of economies of scale in operation as well. Eventually, however, these economies of scale are balanced by increasing costs, say to administration. MC could alternatively be increasing or falling.
[65] Assuming that capacity is not fully utilised. In peak periods where capacity is fully utilised, the price should ideally include the marginal cost of adding additional capacity, necessary to serve the increased demand. For more on peak-load pricing and the optimal distribution of capacity costs see Kahn (1995).
[66] It may difficult to distinguish between the effect of ownership and competitive pressure, though, because publicly owned firms often operate as monopolies while private firms typically are exposed to competition. The competitive pressure may be much more important for cost efficiency than ownership is. While numerous empirical studies have

private firm can introduce stronger incentives for management as well as employees. Layoffs and attractive management salaries may e.g. not be politically acceptable in publicly owned firms. One could also imagine civil servants, administrating the state budget, to be more lenient to management than private stockholders are[67]. Finally, private firms may be able to respond more effectively to changing markets because a larger amount of decisions are delegated to management and because a private board can respond more swiftly than politicians can. The political attitudes in Europe have in fact been changing in favour of privatisation in recent years.

The second proposal for a first-best solution was a subsidised private operator. Subsidising one operator, however, is highly problematic - if not incompatible - with the introduction of competition into the industry - at least in practice. First of all, there is risk of favouring the incumbent, thereby sustaining the natural monopoly. Secondly, a subsidised operator may be less inclined to operate cost effectively, knowing that a deficit will be covered by state subsidies. Due to the asymmetric distribution of information, a subsidised operator may also have an incentive to manipulate his accounts. Furthermore, it may not be politically acceptable to subsidise network industries over other industries. And finally, one should keep in mind that the taxes, financing the subsidies, also distort incentives, and the fact that parts of the redistributed means are lost in administration.

The first-best solution, MC-pricing, is therefore hard to implement and is incompatible with competition between private operators[68]. Thus, it is necessary to design a regulatory framework, which allows the incumbent operator to recover his fixed costs.

Before turning to an evaluation of different proposed pricing rules, allowing this, it is useful first to discuss some overall approaches to regulation, which have been used over the years.

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demonstrated that private firms are indeed more cost effective than public firms are, others have not found any significant difference. Therefore, not all scholars would agree with the viewpoint expressed in the text.
Based on a meta-study of more than 90 studies as well as theoretical considerations, Vining & Boardman (1992) conclude that "ownership also matters and matters a lot." (p.226). More than 2/3 of the investigated studies concluded that private firms were more efficient than public firms were.

[67] In the literature this is known as the "soft budget constraint".

[68] In the railway industry MC-pricing combined with massive state subsidies are used in most Member States, including Denmark, for operation of the tracks. But as opposed to telecom there is no competition over operation of railway tracks, nor any incentive to introduce such competition. An additional argument for MC-prices for railway operation is that railway traffic competes with road traffic where the infrastructure is provided free of charge; prices above MC would therefore bias transport in favour of road transport.

5.2 Cost-plus regulation, price-caps and forward-looking costs

5.2.1 Cost-plus regulation

Under *cost-plus regulation* - also referred to as *rate-of-return regulation* - the regulated firm is allowed to charge a price which actually covers its costs (operating costs + depreciation) plus a 'reasonable' return. Under cost-plus regulation, welfare distortions due to monopoly pricing are avoided. Supply is also ensured because the firm (by definition) can cover its costs. On the other hand, there are no economic incentives for the regulated firm to reduce its costs - to increase productive efficiency; the revenue/the price would just be reduced accordingly. There may even be an incentive to over-invest, if the allowed return is higher than the cost of capital. The latter is known as the 'Averch-Johnson-effect'[69].

The basic problem with cost-plus regulation is the direct link between incurred costs and the regulated price. To provide the regulator with an incentive to achieve productive efficiency, regulation in the 80's and 90's gradually moved from cost-plus regulation to price-cap regulation especially in the UK and the US.

5.2.2 Price-cap regulation

Under *price-cap regulation*, the regulator determines the price that the regulated firm is allowed to charge for its product, say access provision. Initially the price will typically be set equal to the cost-plus price. Afterwards, this price is then regulated more or less independently from the development in the firm's costs. The regulator determines a cost-reduction requirement of X pct., in the sense that the price, adjusted for inflation, is reduced by X pct. a year. Price-cap regulation is therefore also known as *RPI-X regulation*, because the nominal price is allowed to increase by RPI-X per cent each year, where RPI is the increase in the retail price index. Typically, the price will be set as a ceiling, in the sense that the firm is allowed to reduce the price even more[70].

When the price is set to follow such an RPI-X formula, the regulated firm has a strong incentive to reduce costs; each Euro saved increases profit with an equal amount[71].

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[69] Pointed out by Averch and Johnson in "Behaviour of the Firm under Regulatory Constraint", American Economic Review", December 1962, vol. 52, pp. 1052-69.

[70] One may also impose a minimum price to avoid a dominant firm from setting the price extremely low to deter competition. The latter is called "predatory pricing". The issue of predatory pricing, however, is much more relevant for the retail price than for the access price, at least as long as the incumbent has a de facto monopoly over access.

[71] The regulated firm becomes the *residual claimant*. Under cost-plus regulation, consumers are residual claimants.

Price-cap regulation was initially applied to the tariffs of British Telecom (Beesley and Littlechild, 1989). Since then it has replaced cost-plus regulation in many industries particularly in the UK and the US but to some extent also in other EU Member States.

One of the main problems with a price cap, however, is that they do not guarantee that the resulting price reflects the costs of production. If it does not, the result will be an inefficient allocation[72]. Where cost-plus regulation primarily is designed to ensure allocative efficiency, price-caps are primarily designed to ensure productive efficiency.

In the pursuit of allocative efficiency (cost-based prices) and productive efficiency at the same time, a new type of cost-based prices have been proposed and somewhat introduced in telecom in Europe and the US: Forward-looking costs.

5.2.3 Forward-looking costs

Instead of using historic (accounting) costs, costs are estimated on a *forward-looking* basis, which means that the relevant costs are the costs of producing the access or interconnection service if the relevant network were to be build today, using state-of-the art technology and operated by an efficient operator. At least in theory, the link between incurred costs and the regulated price should thereby be eliminated. If the incumbent reduces his actual costs, it should not affect the price he is allowed to charge[73].

From a theoretical perspective, the use of forward-looking costs has another important advantage: costs and capital are valued on the basis of an alternative (economic) cost approach, instead of an accounting costs approach. From an efficiency point of view this is very appealing, because a price based on opportunity costs sends the right signal to consumers about the value of the resources the consumer/the competitor/society is forgoing by using this service.

A forward-looking or alternative-cost-based price is also appealing because it in theory (if calculated correctly and taking into account all relevant costs and synergies) should equal the market price, had the service/product been delivered in a perfectly competitive market. Under competition, accounting costs are irrelevant. When a fixed cost has been incurred, it is sunk if the investment can not be resold. And if it can be resold the value is equal to its best alternative use.

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[72] An additional problem is that the regulated firm has an incentive to under-supply quality. Price-caps should therefore always be accompanied by minimum-quality requirements.

[73] In practice, it probably seems too idealistic to believe that the regulator should estimate costs without having an eye for the actual costs and the accounting value of the regulated firm's capital.

This price may be higher or lower than the originally incurred costs. Typically it will be lower due to depreciation and falling construction costs. But for a product like local loops, however, it may well be higher because of limited depreciation and increased cost of laying down the loops[74]. The value can never exceed the costs of reconstructing the network but may well be lower if an alternative and more cost efficient technology has been developed[75].

Think of a simple example: An incumbent has invested one billion Euro in an access network. Full competition is then introduced into the market, because new technologies remove the natural monopoly of the incumbent. In a fully competitive market with an infinite amount of producers - a market, which of course do not exist outside the theory books of economists - price will be driven down to the costs of the most efficient producer. If an alternative fully substitutable access network can be built at half a billion Euro, the value of the incumbents access network will only be half a billion. The economical value is equal to the present value of the expected future cash flows generated by the access network. But if the incumbent's price is higher than what is necessary to cover an expense of half a billion, there will be entry by an operator using the cheaper technology. In theory the market price, and thus the price of the incumbent, should therefore be driven down to a level set according to the half billion Euro - not the billion Euro that the network originally cost to build.

As should be clear, accounting values may be very different from economic values. First of all, accounting depreciation is unlikely to equal economic depreciation/deterioration. Secondly, substituting products may have been developed which change the expected future stream of cash flows and consequently the value of the infrastructure.

In line with the above arguments, a forward-looking-cost price also has the important attribute of *not* biasing the decision of entrants whether to rent or to build infrastructure. If the price was e.g. set higher than economic/alternative costs, entrants might choose to invest in their own infrastructure even though the costs to society of doing so would be higher than the cost to society of renting the infrastructure from the incumbent. If the price, on the contrary, were set below economic costs, the entrant might choose to rent the incumbent's infrastructure even in a situation where the entrant could build his own infrastructure at lower costs than the incumbent.

[74] More on this below and in chapter 8.
[75] Assuming that the operator has not been granted any special or exclusive rights.

To sum up, the price faced by competitors should reflect the economic/alternative cost of using the infrastructure or service at hand. We are now equipped to look at various proposed pricing principles and cost measures in more detail.

5.3 Selected pricing principles designed to cover (efficient) costs

5.3.1 Long Run (Average) Incremental Costs - LR(A)IC

As opposed to MC, long run average incremental costs (LRAIC) account for scale economies by using the additional ("incremental") cost incurred by the operator in providing the entire service when all other services are maintained at an unchanged level, divided by the number of units of the service produced. Thereby fixed costs are included. Costs are measured in the long run to include operating costs as well as investment costs[76] [77].

LRAIC should imitate the price that would prevail if the (access) service were supplied by a competitive industry. As explained in the previous section, the relevant costs, therefore, are not the actual/historic costs of the incumbent but the costs of an efficient provider, using state of the art technology, and facing current input costs and current expectations about demand. Like under competition, sunk costs are in principal irrelevant for the pricing decision. What matters are opportunity or replacement costs. Hence, LRAIC is a forwarding-looking measure[78]. This is very important to keep in mind and may yield rather surprising results. When pricing access to unbundled local loops e.g., the forward-looking LR(A)IC-standard[79] will, unlike the case of

[76] "Long run" is here defined as the amount of time over which all relevant costs become variable.

[77] One may distinguish between two types of Long Run Incremental Cost (LRIC): "Total Service"-LRIC (TSLRIC) and "Total Element" LRIC (TELRIC). This is done in the US. TSLRIC measures the increment in costs occurring in the long run of offering a complete *service* in addition to other services of the operator. TELRIC refers to the increment in costs that is caused by identifiable *elements*, needed in the production of the service, like e.g. switching or transmission. Where TSLRIC is the appropriate measure for pricing universal service, TELRIC is the appropriate measure for pricing interconnection (WIK 1997) and access to individual network elements (FCC 1998).

[78] Strictly speaking, LRAIC in itself does not have to be forward-looking, but "LRAIC" has become the predominant term in Europe for describing the forward-looking LRAIC of an efficient operator.

[79] The reason why a parenthesis, from now on, consistently is put around "average" is that "LRAIC" has become an established term for pricing interconnection. Here all the relevant incremental costs associated with interconnection provision are added together and then *averaged* out over the total amount of traffic/call minutes, generated by the operators seeking interconnection as well as the operator providing interconnection. For unbundled local loops, however, operators are not just getting access to part of the capacity. They obtain *exclusive* access to the entire capacity of the local loop. The cost to the incumbent of providing such exclusive access is independent of the amount of traffic and hence the rental price should be independent of traffic/call minutes as well in order to achieve allocative efficiency. Consequently, the price should be the entire LRIC of providing this particular network element, the unbundled local loop. When this is said, one could argue that the term 'average' still apply, but in a different

interconnection charges, tend to lead to prices which are higher rather than lower than prices based on historic costs. The reason is that the current-cost-asset-value of the access network is usually higher than the historic cost value, while the opposite is the case for the core network (OVUM 1998, p 72). One may wonder whether politicians are fully aware of this fact when they argue so strongly in favour of using LR(A)IC for the price of unbundled local loops as well.

5.3.2 A "reasonable" profit

To provide the facility-owner with efficient investment incentives in order to obtain dynamic efficiency, the access provider should be allowed to earn a "reasonable" return on his investment. For the return to be "reasonable", it should compensate the firm for the risk associated with the investment and should equal the return the firm could receive if the capital were invested in a project with a similar risk structure. Such a risk-adjusted return or cost of capital can e.g. be estimated using the well-known Capital Asset Pricing Model (CAPM) presented in chapter 6.

It is important to note that the risk, associated with investments in access networks, may differ from industry to industry. For instance, risk is likely to be substantially higher for investments in telecom infrastructure than it is for investments in an electricity network due to the rapid technological development in telecom and the existence of (potential) substitutes.

5.3.3 A mark-up for joint and common costs

A substantial part of a network operator's costs can not be attributed to any particular service. These costs are called *joint and common costs*. They would have to be incurred even if a given service, say access provision, were abandoned and would also exist even if access service were the only service to be delivered. Such costs include general administration, pension liabilities etc. The most straightforward way to cover joint and common costs is to charge a uniform proportional mark-up[80] on all produced services, set to cover these costs. In telecom, most countries have employed such a uniform proportional mark-up. It is an example of a *Fully-Distributed-Costs* (FDC) standard, where all costs are allocated to the to firm's final products

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sense. That is the case when the price is determined on the basis of the entire cost of the access network and then averaged out on all the local loops. Then the price per loop will again be some averaged price - but now usage independent. See chapter 8 for more on the appropriate pricing of unbundled local loops.

[80] A given percentage.

after some specified distribution key[81]. Such a distribution of fixed and common costs is by definition arbitrary: If these costs could be linked directly to the particular services, they would not be *joint and common*. A different way to allocate these shared costs is to allocate them all to the regulated (access) service. Then they are called Average Stand Alone Costs (ASAC) because they are the theoretical costs the incumbent would incur if he were producing only this service. If entrants face the same costs as the incumbent, ASAC thus represents a ceiling for the access price because if the price were higher than ASAC, it would always be cheaper for an entrant to produce the service himself. The two cost-distribution standards are illustrated in figure 5.2 below:

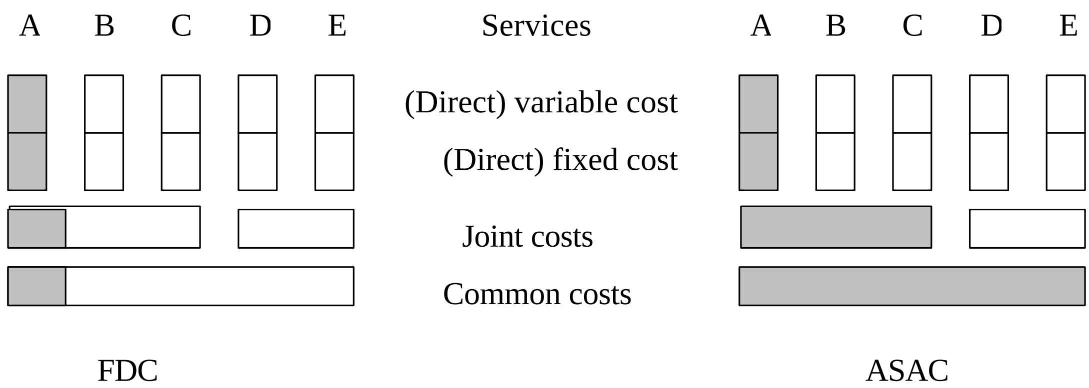

Figure 5.2 - Cost allocation

A regulator will try to distribute joint and common costs in a way closest to the true causal cost structure to avoid cross-subsidies between the services[82]. The incumbent, on the other hand, has a natural incentive to attribute as many of the joint and common costs to the (access) services where he holds a monopoly, thereby minimising the costs he has to recover on his competitive services. If successful, the incumbent can make competitors pay a larger fraction of the joint and common costs and at the same time gain a competitive advantage in the competitive market. Ideally, also the joint and common costs should be calculated on a forward-looking basis to prevent entrants from having to pay for the incumbent's inefficiency.

A more sophisticated approach would be to distribute joint and common costs in order to minimise (allocative) distortion of prices by using so-called *Ramsey prices*.

[81] When using the term fully-distributed costs one is typically referring to distribution of historic/accounting costs.
[82] If 'joint and common costs' are purely joint and common it does naturally not make any sense to talk about a causal cost structure.

5.3.4 Ramsey pricing

The idea behind Ramsey pricing is illustrated with the two simple demand slopes in figure 5.3:

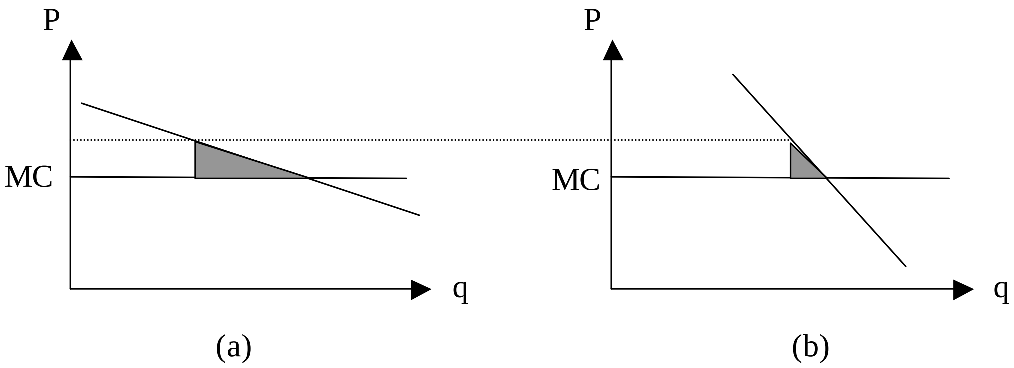

Figure 5.3 - Ramsey pricing, the inverse elasticity rule

Suppose we have some fixed costs we need to distribute on top of MC in order to ensure that the firm breaks even[83]. We can recover these costs on consumers (or services) with a high demand elasticity like illustrated in (a) or instead on consumers (or services) with a low demand elasticity like illustrated in (b). No matter what we do, it will distort prices away from MC. It is clear from the figure, however, that the welfare loss, illustrated by the shaded triangles, is larger for elastic demand because consumers react stronger on a price increase, which in turn implies that the allocation of resources is affected more. This provides the intuition for the so-called *inverse-elasticity rule*[84], which prescribe mark-ups over MC to be inversely related to the price elasticity of demand (ignoring cross-price elasticities). No matter how appealing this seems to economists, however, it is often impossible to persuade politicians to follow such a rule because the consumers with inelastic demand typically are private low-income consumers[85].

5.3.5 The Efficient Component Pricing Rule (ECPR)

The idea of the *Efficient Component Pricing Rule* (ECPR) also referred to as the *Baumol-Willig rule*[86] is to add an opportunity cost mark-up to the cost of access provision. An opportunity cost, which arises from delivering only access provision instead of the entire services.

[83] These costs could be joint and common costs but they could also be costs associated with Universal Service provision for example.
[84] Proposed by Ramsey in 1927 in "A contribution to the Theory of Taxation", Economic Journal Vol. 47
[85] It may possibly also violate the non-discrimination requirement of general competition law.
[86] It was proposed by Robert Willig in 1979 and popularised by William Baumol in numerous regulatory proceedings and writings (Laffont & Tirole, 1996).

The rational for such an approach is that the incumbent is subject to regulatory price restrictions as well as a break-even constraint. With unbalanced tariffs, entrants can target markets made profitable by these regulatory restrictions such as e.g. long distance telephony. The incumbent would then lose the source financing the subsidy scheme in place. To avoid this as well as to avoid inefficient entry, the incumbent should, the argument goes, be allowed to cover this loss via the access price.

Figure 5.4 is an attempt to illustrate the reasoning behind the ECPR:

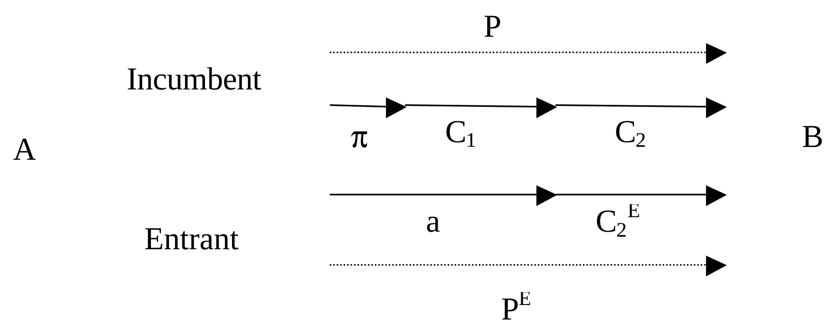

Figure 5.4 - The Efficient Component Pricing Rule

Consider a service consisting of connecting A to B. This service has two components: Access provision as well as delivering the actual call to B. The last part could reflect long distance telephony or some value added service such as Internet service provision.

Earlier the incumbent delivered the entire product at a price P, sufficiently large to cover his costs, C_1 and C_2, as well as a profit margin, π, which was partly used to subsidise other services. Now, an entrant wishes to enter by buying the first part (access) from the incumbent and then provide the second part to the consumer himself.

According to the ECPR, the appropriate access price, a, should then be set at $C_1 + (P-C_1-C_2) = P - C_2$[87]. The term in parenthesis is the opportunity-cost term, i.e. the incumbent's loss in profit, π, caused by the entrant supplying an extra unit of the service. Suppose the entrant's cost of delivering the last part of the product is C_2^E. In order not to lose money, the entrant will have

[87] In this simple version of the ECPR the product of the entrant and the retail product of the incumbent have been assumed to be perfect substitutes: one unit of production by the entrant replaces one unit of production by the incumbent. If the two products were not perfect substitutes, the formula should be changed to $a = C_1 + \sigma\,(P-C_1-C_2)$, where $0<\sigma<1$ is the displacement ratio, expressing how large a fraction of the incumbents production is lost when the entrant produces one extra unit. If the incumbent does not lose anything by allowing the entrant access, the access charge should be set equal to the direct costs of access - there is no opportunity cost. For more on this, see e.g. Armstrong (1997).

to charge a price of at least $P^E = a + C_2^E$. At the same time, the entrant will only enter if he is able to undercut the incumbent's price. Profitable entry therefore requires:

$$P^E < P \quad \Leftrightarrow \quad a + C_2^E < P \quad \Leftrightarrow \quad P - C_2 + C_2^E < P \quad \Leftrightarrow \quad C_2^E < C_2$$

An access prices set according to the ECPR thus ensures that entry only takes place if the entrant is more cost efficient than the incumbent is. The ECPR was designed to accommodate efficient entry, while still protecting the incumbent's ability to cross-subsidise certain consumers[88].

A main problem with the ECPR rule is that it does not provide the incumbent with any incentive to reduce neither his costs nor his retail price. The incumbent makes the same profit from the customer whether or not he retains this customer's business or lose it to the entrant[89]. Furthermore, the higher the retail price is, the higher the access price can be! If the incumbent is producing inefficiently, entrants pay for the inefficiency - not the incumbent. This is unacceptable of course, which is why the ECPR has been the subject of fierce criticism. The ECPR could end up being a "rationalisation for the continued collection of the monopoly profit despite the introduction of competition" (Laffont & Tirole 1996 quoting Kahn & Tyler).

In response to this criticism it is fair to point out that the ECPR was designed assuming the existence of an appropriate regulatory framework to control the incumbent's monopoly power, other than through access pricing (Cave, Crowther and Hancher 1995). The ECPR only provides a link between access prices and retail prices. Thus, it is a partial rule and its optimality depends on retail prices being set at the optimal level. The ECPR is often presented without mentioning this. It is more correct to criticise the usage of the ECPR in a world where final prices are unlikely to be regulated at their optimal level, rather than to criticise the ECPR itself. When this is said, though, one should not forget that competitors would still be paying for any cost inefficiency of the incumbent, and that the incumbent only has limited incentives to eliminate these inefficiencies under an ECPR.

A second disadvantage of the ECPR is that it may encourage *inefficient by-pass* if tariffs are very unbalanced. If the entrant is seeking access in order to provide a competing service, which in the past has contributed substantially to the incumbents profit through a relatively high

[88] Acknowledging also that access charges can be used to lower the incumbent's retail prices, a Ramsey term should be added to the simple ECPR rule (see Armstrong 1997).
[89] This has also been used as an argument in favour of ECPR, however, because it ensures that the incumbent has no incentive to discriminate against the entrant e.g. through a reduced quality of access.

retail price, the entrant will face a very high access price. A price that may be higher than the stand-alone costs of the access service. Then it is profitable for the entrant to by-pass the incumbent's infrastructure, even though the cost of doing so is substantially higher than the cost at which the incumbent could have provided access. All other things equal, ignoring the indirect benefits of entry, society thus loses.

From a welfare point of view, it is always problematic when the price of a product depends on the use to which the product is put, instead of the cost of its provision alone. Usage based prices are also hard to implement because they require information about elasticities (and cross-elasticities!) of demand. Not only may elasticities be difficult to estimate[90]; the information is also asymmetrically distributed with the incumbent, leaving him the opportunity to manipulate the regulator. The ECPR also requires information about the incumbent's margins and marginal costs on the competitive segment. The incumbent may try to manipulate this information as well.

On the other hand, ECPR somewhat protects entrants from predatory pricing by tying the retail price to the access price. The incumbent cannot dump retail prices without also lowering access prices. In this sense the ECPR is similar to the avoided-cost approach, discussed below.

The British National Regulatory Authority, Oftel, used to apply usage-based access prices in the past. For example the competing operator, Mercury, paid a different (higher) access fee when access was used to provide an international call than when a domestic call was provided (Laffont & Tirole, 1996). And in October 1994 the Privy Council in London upheld an earlier ruling in New Zealand about the ECPR being the appropriate principle for pricing interconnection between the incumbent, Telecom Corporation of New Zealand, and the entrant, Clear Communications Ltd. (Muller 1998). Mueller (1998) concludes that the adoption of the ECPR in New Zealand did not offer a satisfactory solution to the interconnection problem.

5.3.6 Avoided-cost pricing and competitive margins

The avoided-cost approach links the access price to the retail price, as the ECPR does. However, while the ECPR is primarily designed to protect the incumbent and his cross-subsidy scheme, avoided-cost prices are designed to protect entrants. Entrants are allowed access to an incumbents services on a wholesale basis, at a price equal to the incumbents retail price minus XX per cent, corresponding to the costs avoided by the incumbent when the product is sold by the entrant, say

[90] The problem is larger in rapidly changing industries such as telecom than it is in, say electricity distribution.

billing and marketing costs. As opposed to the ECPR, no opportunity cost is added to the access price. In telecom, service providers/resellers have usually been allowed to enter into an agreement of service provision with the incumbent at such an avoided-cost price, which ensures the entrant a minimum margin on which to compete[91]. Price squeezes by the incumbent (a low retail price combined with a high access/interconnection price) is hereby avoided. The Commission has recently considered such price squeezes to be a current problem in telecom[92].

A main problem with avoided-cost prices and regulated margins to compete on, is the estimation of the avoided costs. One may suspect these competition margins to be set without sufficient investigation into the cost structures. These margins should be set on a service by service basis and not as a general discount[93].

Another important problem is that retail prices are not always cost oriented. And even if they were, a strict relationship between wholesale prices and retail prices would still lock new entrants into the same retail tariff structure as that of the incumbent. This prevents development of innovative retail tariff schemes targeted at different types of users (Commission 1997)[94].

5.3.7 A global price cap

A final approach has been suggested by Laffont & Tirole (1996). They propose subjecting the incumbent to a *global price cap,* covering the access price as well as the retail price, instead of regulating the two prices separately. Hereby, some of the pricing decision is decentralised from the regulator to the incumbent, allowing the latter to use his superior knowledge about demand and cost structures to implement the Ramsey prices discussed in section 5.3.4. The incumbent's incentive to manipulate information about costs and demand is also strongly reduced.

Instead of a uniform mark-up to cover joint and common costs and to fund the access deficit, the operator is allowed to charge different mark-ups on access provision and retail call prices. The operator then has an efficient incentive (the argument goes) to minimise distortion on demand by implementing Ramsey prices where mark-ups are inversely related to demand elasticities. "The firm is led to view competitors' output as an output of its own, that it partly

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[91] In Denmark legislators have fixed this wholesale price for interconnection at the retail price minus 21per cent (§ 7(10) of Act No. 470 of 1 July 1998 about inter alia interconnection pricing. http://www.folketinget.dk
[92] See the Commission's 5th report on Implementation of the telecommunications regulatory package. http://www.ispo.cec.be/infosoc/telecompolicy/5threport.html
[93] See footnote 91**.** The 21-per-cent margin appears to apply over a range of different services.

produces (in the bottleneck segment) and partly outsources (in the competitive segment) if it is efficient to do so." (Laffont & Tirole 1996, p.231).

In its simplest form, such a global price cap can be expressed by the following inequality:

$$w_0P_0 + w_1P_1 + w_2a \leq \overline{P},$$

where 'w' are weights, 'P' the prices, and 'a' the access price. '0' represents the bottleneck facility, say local telephony, and '1' the competitive segment, say long-distance telephony. To achieve a Ramsey-price structure the weights should be exogenous and set equal to the actual quantities of each service[95].

Under the global price cap, however, there is an incentive to prey on competitors by lowering the retail price while increasing the access price if this can force out competitors. Furthermore, it is true that a rational incumbent should realise that he could make more profit by outsourcing production in the competitive segment when competitors are more cost efficient than the incumbent's retail division is. In reality, however - leaving aside the 'economic man' for a minute - the incumbent may still want to favour its own retail division, simply because management *perceives* this to be beneficial. The incumbent may e.g. irrationally think of the situation as a zero sum game, where he earns what his rivals lose. Furthermore, the relationship between the wholesale division and the retail division of the incumbent is bound to be closer than the relationship between the wholesale division and competitors.

“Rationally or not”, the wholesale division of the incumbent may therefore have an incentive to subsidise its retail division. If in fact an inefficient producer of the competitive service is chosen, it is irrelevant whether this is due to rational greed or to a bureaucratic firm, failing to exploit opportunities. In both cases, a welfare loss is incurred. In a competitive industry, a badly managed firm would only hurt itself. If the firm has market power, however, it might hurt consumers as well. Discrimination against competitors in the downstream market is called *monopoly leveraging* because the firm is trying to extend its monopoly in the upstream market to the downstream market[96].

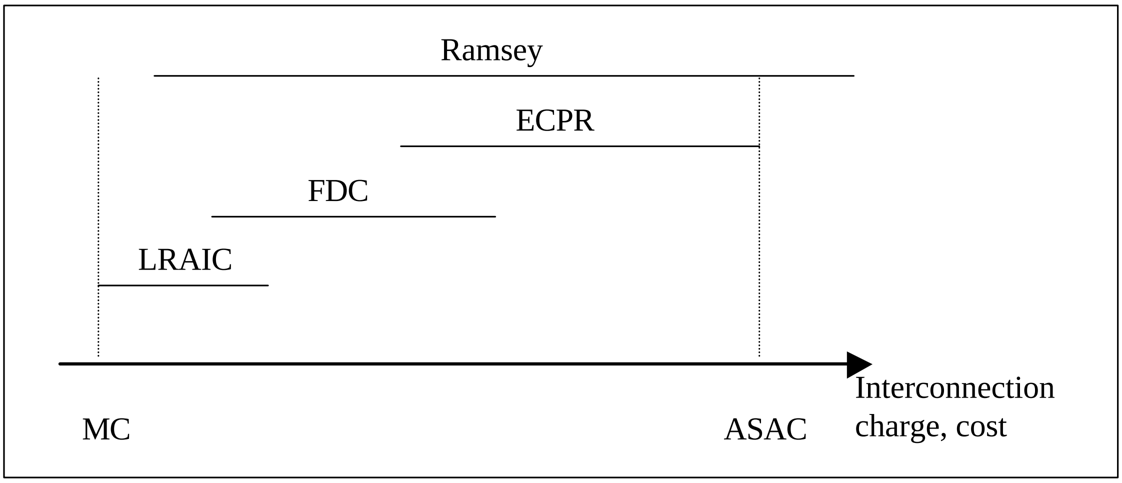
[94] Commission (1997): Recommendation on Interconnection in a liberalised telecommunications market. Part 1. Annex 1 section 4 http://www.ispo.cec.be/infosoc/telecompolicy/en/A3148-en.doc

[95] If weights are not exogenous, so that the regulated operator can influence the weights by his pricing decision, he will do so. Profit maximisation will then no longer lead to an optimal outcome.

[96] This irrationality argument has been pointed out earlier in the context of monopoly leveraging (see Holm 1998).

Anyhow, it does not really seem to matter whether the incumbent would in fact discriminate against competitors or not if the competitors and the politicians suspect them to do so. No matter how interesting and appealing the proposal of Laffont & Tirole may seem in theory it is therefore unlikely to gain political acceptance. Finally, it is worth noting that the global price cap of Laffont & Tirole was proposed in a context of a substantial access deficit as an answer to the question of how to minimise distortion and still finance the access deficit. Such a solution will also always be 'second-best' compared to the elimination of the access deficit through tariff rebalancing or alternatively financing universal service via a universal service fund to which all operators contribute - not only the operators requiring access to the incumbent's network.

The outcomes of the described pricing principles are compared in figure 5.5:



Source: WIK, 1994, p 79 (taken from Cave, Crowther and Hancher 1995)
Figure 5.5 - Comparison of different access pricing principles

5.3.8 Interim summary

Based on the above discussion of the proposed pricing principles, one may conclude that as long as the access deficit and the Universal Service Obligation can be financed via a Universal Service Fund or even better partly eliminated through rate rebalancing, cost-based prices should be pursued. The price should cover short run as well as long run costs. Hence, LR(A)IC is the appropriate measure of costs. On top of LR(A)IC, a mark-up for joint and common costs should be added, including a reasonable return on the invested capital. To achieve allocative as well as dynamic efficiency, costs should be forward looking, thereby imitating the price in a competitive industry with free entry and exit. Such a price should ensure (long run) allocative, productive as well as dynamic efficiency (see e.g. Economides, 1999). This is only true, though, if the regulated operator is allowed to charge cost-based prices for the remaining services as well, sufficiently high to cover operating and investment costs as well as a reasonable return on invested capital[97].

This view seems to be widely accepted at least in a world where the operators can not postpone their investments or in a world of certainty. Recently, however, some economists have argued that dynamic efficiency will not be obtained unless uncertainty and the regulated operator's (real) option to postpone his investment are properly incorporated in the analysis. We return to this question in the following chapters, where a theoretical framework, necessary to evaluate and thoroughly understand this claim in detail, is constructed.

5.4 Estimating LR(A)IC

It would be beyond the scope of this thesis to go into detail with cost estimation and cost accounting. A whole thesis could be written on this topic alone. The purpose of this section is only to point out the difficulties and the high degree of uncertainty associated with such estimation. Many models have been suggested. They can be divided into two types: A top-down (accounting) approach and a bottom-up (engineering) approach.

The *top-down approach* uses the accounting costs and book values as the point of departure and then works the way down towards the service or infrastructure element at hand. The main problem here is cost allocation and evaluation of the degree to which these costs arise from an efficient production (costs arising from inefficiencies should be eliminated).

The *bottom-up* approach constructs a theoretical network using traditional telecom plant design with the best available technology, scaled to meet current demand[98]. In telecom numerous cost models have been developed in the US such as e.g. the Hatfield Model[99]. In Europe WIK has developed a generic (non-operator specific) cost model for the local access network in Germany on behalf of the National Regulatory Authority, Reg TP[100].

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[97] Whether the reasonable return is included in the cost or capital is a matter of definition.
[98] If calculated correctly, the top-down and the bottom-up approach should yield similar prices. Reconciling the two approaches is likely to be a difficult task, but it would indicate that the price were correctly estimated.
[99] Developed by Hatfield Associates Inc (http://www.hai.com) for AT&T and MCI.
[100] WIK (1998): "An Analytical Cost Model for the Local Network", Consultative document of 4 March 1998 to Die Regulierungsbehörde für Telekommunikation und Post.
http://www.regtp.de/imperia/md/content/reg_tele/anakosteng/2.pdf

Building such an economical/engineering model, however, is a very complicated task, which not only requires engineering decisions about how to construct the network and what technology to use, but also requires estimates for the value of capital, depreciation, reasonable (risk-adjusted) return, operating costs, demand and traffic volume etc. Not only does this mean quite a number of subjective estimates but it also poses a more fundamental problem as pointed out by e.g. Alleman (1999). The engineering models begin with an estimate of demand and then design the system accordingly. In the end, total estimated costs are divided by demand to find the price needed to cover costs. But this ignores the effect price has on demand. Demand is endogenous, unless one is willing to assume perfectly inelastic demand. Ideally, capacity and demand should also be allowed to evolve over time. According to Alleman (1999) cost models typically assume that the network is build at once and that demand remains constant.

When constructing the fictive network, regulators also have to consider whether to use a network, built the way one would build such a network today - the so-called *"Greenfield approach" or "scorched-earth approach"* - or whether to take the existing network configuration as point of departure - the so-called *"scorched-node approach"*. All other things equal, the Greenfield approach should result in the lowest price: One can copy the present network but has the option to build it differently if this can reduce costs[101].

It should clear that estimating LR(A)IC is a complicated task that requires many subjective estimates of the modellers. Due to the complexity of the calculation, the asymmetric distribution of information and the strong incentives for the incumbent as well as for entrants to bias the price, it seems appropriate to conduct these estimations through a co-operation between the incumbent, the entrants and the regulator. More on LR(A)IC-based prices in chapter 7.

5.5 Infrastructure competition versus service competition

An additional question, which regulators have been discussing during the last couple of years, is whether to pursue infrastructure competition or service competition. The question is primarily relevant in telecom where costs of alternative infrastructure are decreasing due to rapid technological development. In other network industries such as electricity and gas the economies of scale are so large that competing networks are unlikely to be constructed.

[101] In practice, most (if not all) cost models have used a scorched-node approach, though.

Infrastructure competition refers to a situation where the incumbent faces head-to-head competition from entrants, who are using their own (access) networks - their own infrastructure. This infrastructure may consist of traditional copper wires or substituting technologies such as CATV, fixed wireless, satellite etc. Proponents of infrastructure competition would argue that full head-to-head competition is necessary to stimulate efficiency and innovation and that it allows different technologies to compete against each other. Finally, it also provides the regulator with a yardstick for benchmarking the incumbents reported cost data.

Under *service competition,* operators compete on the services provided whether they are provided over the incumbent's existing network or otherwise. Operators may e.g. be pure resellers, who only resell the services of the incumbent and maybe repackage these services with the services of other operators, say mobile operators. Proponents of service competition focus on avoiding the costs of network duplication.

If a regulator wants to stimulate infrastructure competition, he should set the access price relatively *high* in order to make investment in alternative infrastructure more attractive than rental of the incumbent's infrastructure. Investment incentives may also be stimulated by not subjecting entrants to the same restrictive regulation that applies to the incumbent. With regard to physical access to the infrastructure such as access to unbundled local loops, a regulator, favouring infrastructure competition, would hesitate to require such access. This was previously the British NRA Oftel's main argument for not requiring local loop unbundling.

If the regulator, on the other hand, were primarily preoccupied with achieving competition over services as quickly as possible, he would favour a relatively *low* access price in order to encourage entry by competitors. The regulator would favour local loop unbundling in order to enable entrants to offer sufficiently competing services such as e.g. broad band access to the Internet. This has been the argument for requiring access to unbundled local loops at cost-based prices in e.g. Denmark and Germany[102].

The discussion of infrastructure competition versus service competition is somewhat misleading, though, since the two kinds of competition are not mutually exclusive. It seems perfectly possible to pursue service competition and infrastructure competition at the same time.

[102] In Denmark another argument for local loop unbundling was the development of the new product, *Duet*, which combined the mobile and the fixed phone. In order to be able to offer a similar product, competitors needed access to the local loop. The fear was that the Incumbent, Tele Danmark, otherwise would try (ab)use its monopoly over fixed

Initially, it is necessary to allow entrants access to the incumbent's infrastructure to allow them to build-up a critical mass of customers. Then as competing infrastructure is built out, regulators can gradually reduce the scope of regulation. In an industry where economies of scale exist but are still limited compared to other network industries, infrastructure competition should naturally be the ultimate goal for regulators since true competition will always lead to a better result than even the most sophisticated kind of regulation. As long as entrants do not possess their own infrastructure, though, a need for wholesale regulation will persist no matter have intense the competition over retail services is. But it would be wrong to focus on infrastructure competition only since this would slow down the liberalisation process. In the extreme case, investments in alternative infrastructure might even be reduced. That would be the case if potential competitors e.g. decide not to enter the market due to lack of access to unbundled loops. Therefore, regulators should concentrate on setting an access price that does not bias the decision between renting or building competing (access) network infrastructure. Such a decision is best left to the industry as long as the players face the true cost of each alternative, which at least in theory, they would if the market for access were competitive. As mentioned above such an unbiased price seems to be Forward Looking LR(A)IC plus a mark-up for joint and common costs and a reasonable profit.

5.6 A Practical alternative to cost-based prices: Benchmark-regulation/Best current practice/Yardstick competition

As should appear from the previous discussion, the theoretically appropriate access price is LR(A)IC plus a mark-up for joint and common costs and a reasonable profit. In practice, however, calculating LR(A)IC is extremely complicated and will involve a number of estimates and assumptions. The resulting price is therefore likely to have a rather broad confidence interval. Because of these difficulties, it will take a lot of time to implement LR(A)IC prices. Furthermore, it may not be satisfactory to the industry that the price depends on who is doing the calculations.

An alternative and far more simple way to regulate access prices would be to apply some kind of benchmark-regulation under which the price is set according to some relevant benchmark such as e.g. the price of other similar operators. In addition to being simple, this approach

access to gain a competitive advantage in the mobile market as well. For more on this see Holm (1998). A similar reasoning can be applied to high bandwidth access to the Internet.

benefits from relying (indirectly) on the costs of other similar operators instead of the operator's own costs. Thereby the firm can cut down costs and increase efficiency without fearing that the obtained efficiency gain is balanced with a lower price. On the other hand, if the operators who serve as benchmarks are not producing under conditions similar to those of the regulated firm, the independence of costs turns into a problem instead of an advantage. But as long as the relevant operators do operate under similar conditions and these other operators are capable of making a profit, it will be hard for the regulated firm to claim that it receives unfair treatment. If the operator is not making a profit, it is simply because he is producing inefficiently.

In the EU, the Commission has recommended that interconnection prices should temporarily be regulated according to a special kind of benchmark regulation, the so-called "*best current practice"*, until the implementation of LR(A)IC-prices. Here the relevant benchmark is set to be a price range, spanning from the price in the cheapest Member State to the price in the third-cheapest Member State[103]. Starting 1 January 1998, "best current practice" was 0.6-1 ECU for call termination at the local level at peak rate[104].

Figure 5.6 below illustrates the development in local call-termination charges after the introduction of this "best current practice". Even though charges have not fallen into the best-current-practice range in all Member States after publication of the charges, it is clear that it has had a substantial effect in those Member States where charges were previously much higher than the upper limit of the price rang, 1 ECU (Euro).

In Denmark legislators have recently decided to take this a step further by pursuing a "best and cheapest in the world"-requirement for telecom services, introducing a best current practice where a *single* interconnection agreement can be used as the relevant benchmark (as an alternative to the present three)[105]. The requirement is that the benchmark operator operates under conditions and cost structures similar to those of the Danish incumbent and that the employed price reflects a stable level[106].

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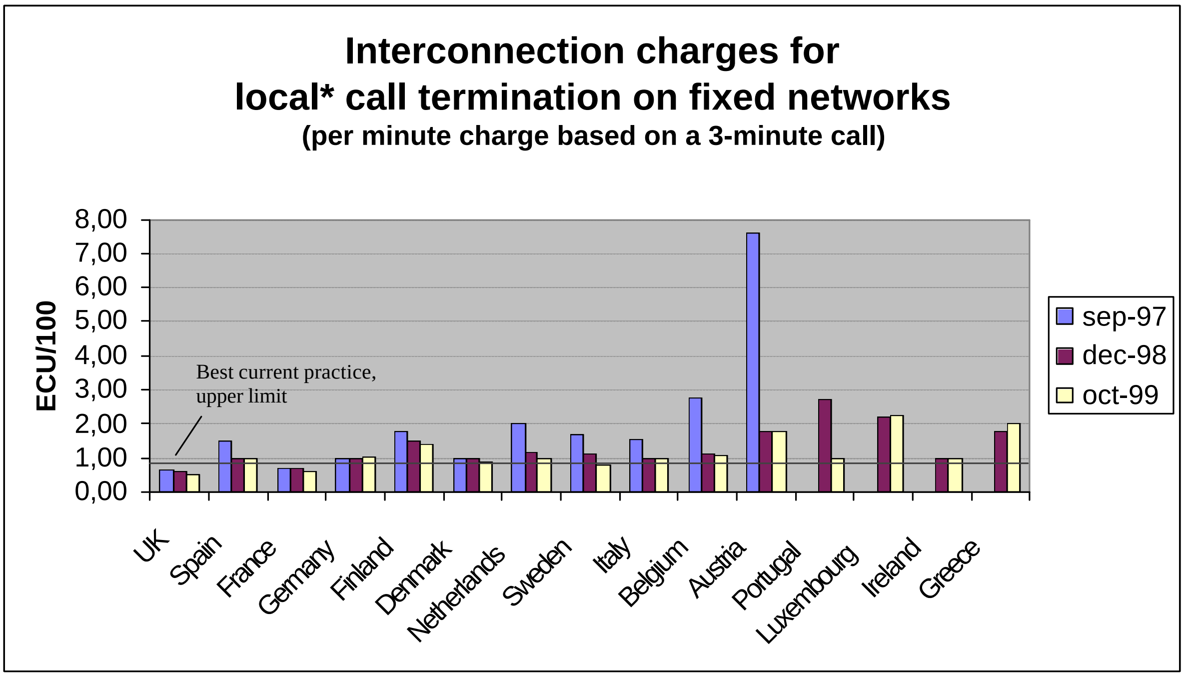
[103] An alternative much weaker approach could have been to use the average over Member states.
[104] A "best current practice" for "single transit" (metropolitan area) and "double transit" (national level) has been developed as well.
[105] §55(3.1) of Bill L248 of 30 March 2000 on law about competition and consumer issues for telecommunications, http://www.fsk.dk/fsk/div/love/l248.doc
[106] The Danish national regulator, Telestyrelsen has already lowered Tele Danmark's prices by 15, 35 and 20 per cent for local transit, single transit, and double transit respectively based on a study on interconnection prices in Denmark, UK, Germany and Sweden. This was done according to the existing legislation, §7(7) of act No. 470 of 1 July 1998, which has been interpreted as requiring more than one country as the relevant benchmark. These figures were set conservatively at the low end of the estimated range due to the uncertainty associated with the study. Decision of 28



*) Local': A call handed over for termination at the local level represents interconnection at (or nearest to) the local exchange to which the destination user is connected, and represent the lowest level of interconnection charge which is available in a given country. To allow comparison between Member States, the peak rate is used.
Sources: Commission (1997), Commission (1998), and Commission (1999)[107].

Figure 5.6

Such an approach raises a new problem if tariffs are not fully rebalanced in the benchmark countries. If interconnection charges are cross subsided 'more' abroad than at home, the national operator will incur a loss because only the foreign cross subsidised price is forced upon him, not the foreign prices financing the cross subsidies[108]. The problem increases if certain (access/interconnection) prices are cross-subsidised in one country and other (access/interconnection) prices are cross-subsidised in another country. Then entrants/the regulator can pick the cheapest price for each interconnection service in different countries. If this is allowed, the regulated operator may end up with a basket of prices, which are all below costs and the operator will not be able to make a reasonable return on capital even though the

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September 1999. http://www.tst.dk upheld by decision of 1 February 2000 by The Telecommunications Complaint Board http://www.teleklage.dk/aarsberet/afgoerelser/9900197.htm

[107] Commission (1997): Recommendation on Interconnection in a liberalised telecommunications market. Part 1. Annex 2. Commission (1998) communication: Interconnection in Member states, 1st of December 1998. Commission (1999) communication: Interconnection in Member states, 1st of October 1999.

[108] In its complaint to Telestyrelsen, regarding the lowering of its interconnection prices, Tele Danmark inter alia argued that the interconnection prices of British Telecom were cross subsidies by high prices for leased lines. The regulator dismissed this complaint. See previous footnote.

benchmark operators are. Even when tariffs are balanced and overall costs are comparable in the benchmark countries, the same problem arises if the costs of producing the individual services differ between the countries. When combining best practice with a "best and cheapest requirement" it is therefore important not to allow such "cherry picking".

Finally, it should be pointed out that cost differences between EU Member States may occur as a result of factors such as average density of connections, labour costs, or permitted rate of return on capital employed. According to the Commission, however, the range used for "best current practice" should be sufficiently large to allow for such differences[109]. But if one wishes to apply a best practice with the cheapest operator only as the benchmark, it is definitely necessary to take these possible cost differences into account.

An alternative way to implement benchmark regulation would be to use costs instead of prices of other international network operators. If the prices of the national operator were set on the basis of the most cost-effective foreign operators, working under similar conditions as the national operator, the concept of efficiently incurred costs would gain new meaning. The regulator would be able to point to actual operators instead of a theoretically constructed generic network. Such a cost analysis could e.g. be made, by using Data Envelopment Analysis (DEA). This kind of benchmark regulation will be applied to the Danish electricity distribution companies, operating the local access/distribution networks. Here the benchmark operators will be other national operators[110]. In telecom there is typically only one large fixed-access provider in each country, which is the reason that international benchmarking is required.

The idea of regulating prices according to the cost of similar companies was originally proposed by Shleifer (1985) and termed "yardstick competition". The basic idea is that prices do not depend directly on the regulated operator's own cost, which will give him efficient incentives to obtain own productive efficiency. The interesting attribute of such a regulatory framework, absent collusion and absent regulatory uncertainty, is that it provides operators with incentives to act *as if* they were competing with each other in the same market - hence the term *yardstick competition.*

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[109] Commission (1997): Recommendation on Interconnection in a liberalised telecommunications market. Part 1. Annex 2 section 1 http://www.ispo.cec.be/infosoc/telecompolicy/en/A3148-en.doc

[110] For more on the regulation of the Danish Electricity Distribution companies, DEA analysis and Income cap regulation see Holm (1999).

The latter approach should only be applied to services with a substantial degree of operating costs and new investment costs compared to already undertaken investments. Otherwise prices will depend too much on the accounting approach of the benchmark operators. Hence, it would e.g. not be appropriate for the pricing of unbundled local loops.

5.7 EU legal framework for pricing access/interconnection in telecom

In addition to the competition law Articles 81, 82 and 86 and Article 145 (Trans-European networks) of the European Treaty discussed in chapter 3[111], access/interconnection in telecom is regulated according to harmonised sector-specific regulation, in particular the so-called ONP (Open Network Provision) Directives:

- The Leased Line Directive[112], which deals with access to and use of leased line services
- The Voice Telephony Directive[113], which deals with access to and use of public telephone networks and services, and
- The Interconnection Directive[114], which deals with interconnection of and access to public networks and services in general.

As emphasised by the Commission in its access notice[115] the competition rules continue to apply also where sector-specific legislation is applicable. The two are mutually reinforcing: Where appropriate, "*the ONP framework will be used as an aid in the interpretation of the competition rules*" and "*application of the competition rules is likewise required for an appropriate interpretation of the ONP principles."*[116]

[111] Presented in full in appendix A.
[112] Council Directive 92/44/EEC of 5 June 1992 on the application of Open Network Provision to Leased Lines (OJ L165, 196.92 p.27) as amended by Directive 97/51/EC of the European Parliament and of the Council of 6 October 1997 (OJ L 295, 29.10.97 p.23) and Commission Decision 98/80EC of 7 January 1998 (92/44/EEC OJ L 014, 20.01.1998 p. 27)
[113] European Parliament and Council Directive 98/10/EC of 26 February 1998 on the application of open network provision to voice telephony http://www.ispo.cec.be/infosoc/telecompolicy/VT/ONPVTEN.pdf
[114] Directive 97/33/EC of the European Parliament and the Council of 30 June 1997 on interconnection in telecommunications with regard to ensuring universal service and interoperability through application of the principles of open network provision (ONP) as amended by Directive 98/61/EC of the European Parliament and the Council of 24 September 1998 with regard to operator number portability and carrier pre-selection (OJ L 268, 03.10.1998 p.37)
[115] Commission (1998): "Notice on the Application of the Competition Rules to Access Agreements in the Telecommunications Sector", 31 March 1998. http://www.ispo.cec.be/infosoc/telecompolicy/en/ojc265-98en.html
[116] Commission's Access notice (see previous footnote). Part III: Principles.

The ONP directives impose certain obligations of transparency, non-discrimination and pricing as well as an obligation to supply (interconnect) that go beyond those imposed under Article 82. The Interconnection Directive first of all requires operators to accept any reasonable request for interconnection. Second, it requires accounting separation "*showing the main categories under which costs are grouped and the rules used for the allocation of costs to interconnection*"[117]. With regard to non-discrimination the Interconnection Directive stipulates that interconnection agreements must be communicated to the NRA and made available to interested third parties[118]. Also a "reference interconnection offer" (standard agreement) should be publicly available[119]. Concerning the price, the Commission recommends[120] the use of forward-looking LRAIC plus a mark-up for forward-looking joint and common costs of an efficient operator[121]. Until forward-looking LR(A)IC based prices have been implemented the Commission recommends basing prices on 'best current-practice' (described above)[122]. Only the interconnection price of operators with *significant market power* is regulated, where an operator is presumed to have significant market *power "when it has a share of more than 25 % of a particular telecommunications market in the geographical area in a Member State within which it is authorised to operate"*[123]. Finally, all terms of interconnection agreements, including a refusal to interconnect, should be o*bjective*.

These obligations are enforced in the Member States by independent National Regulatory Agencies (NRAs), operating under national law, albeit implementing EU law. NRAs also have jurisdiction to take steps to ensure effective competition[124].

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[117] Interconnection Directive Article 7(5) - elaborated in Commission Recommendation of 8 April 1998 on interconnection in a liberalized telecommunications market. Part 2 - Accounting separation and cost accounting http://bscw2.ispo.cec.be/infosoc/telecompolicy/en/Main-en.htm

[118] Article 6(c)

[119] Standard agreements allow entrants to skip timely negotiation when interconnecting with the incumbent.

[120] Commission Recommendation of 15 October 1997 on Interconnection in a liberalised telecommunications market. Part 1 - Interconnection Pricing, http://bscw2.ispo.cec.be/infosoc/telecompolicy/en/r3148-en.htm

[121] Recommendation 3. Alternatively, NRAs could require that common costs be recovered on call origination, but not call termination. The underlying aim should be to ensure that common costs are not allocated in a disproportionate way to less competitive services. Footnote 10 of Commission Recommendation of 15 October 1997 (see previous footnote).

[122] Recommendation 4 of 15 October 1997. In Denmark, where a best current practice has been implemented, legislators have decided that access/interconnection prices should be based on FL LRAIC from 31 December 2002. To the extent that LRAIC prices can be established prior to this date, the price for access to unbundled local loops and collocation have the highest priority. Commentary to § 55(8) of Bill L248 of 30 March 2000 on law about competition and consumer issues for telecommunications, http://www.fsk.dk/fsk/div/love/l248.doc

[123] Article 4(3) of the Interconnection Directive.

[124] Interconnection Directive Article 9(3). National regulatory authorities may nevertheless determine that an organization with a market share of less than 25 % in the relevant market has significant market power. They may

It is worth mentioning one specific principle, advocated by the Commission, which is that of not incorporating the costs of the access network, when estimating the costs associated with switched access[125], such as call termination and call origination. This is based on the reasoning that the costs of the access network should be financed by end users via the rental charge.

5.8 Non-price issues:

The thesis focuses on the question of whether to grant access and if so at what price. From a legal and particularly economic point of view these are the most interesting questions. However, regulators should not forget that even when access has been granted and the price has been determined, the incumbent may still be able to abuse his dominant position in order to gain a competitive advantage over competitors. Connection may deliberately be delivered and repaired with a delay, quality might be reduced and the incumbents technical division might pass information about who a customer is switching to on to the sales division, which can then target this customer with a price sufficiently low to undercut the entrant etc.[126].

To the extent that the regulator ex ante can regulate the non-price access terms without removing too much flexibility for the incumbent and entrants, such regulation should be enforced and backed-up by sanctions such as e.g. fines for delays. But for many access terms, problems may be impossible to foresee or impossible to regulate ex ante. To deal with such questions it would be appropriate for regulators/legislators to introduce some kind of code of conduct for negotiating in 'good faith' as well as a framework for dispute resolution and sanctioning. Such measures have recently been proposed by OVUM (1999).

also determine that an organization with a market share of more than 25 % in the relevant market does not have significant market power. In either case, the determination shall take into account the organization's ability to influence market conditions, its turnover relative to the size of the market, its control of the means of access to end-users, its access to financial resources and its experience in providing products and services in the market. 'Significant market power' generally describes a position of economic power in a market less than that of 'dominance' used under competition law (Commission Access notice, 1998, footnote 58)

[125] Access using one or more of the incumbents switches, as opposed to physical access to the local (copper) loop. The two types of access are illustrated in chapter 8, figure 8.1.

[126] Article 6(d) of the Interconnection Directive (97/33/EC) explicitly requires that "*information received from an organization seeking interconnection is used only for the purpose for which it was supplied. It shall not be passed on to other departments, subsidiaries or partners for whom such information could provide a competitive advantage*"

Chapter 6

Real options[127]

> *"The new view of investment opportunities as options* [..] *has shown that the traditional 'net present value' rule, which is taught to virtually every business school student and student of economics, can give very wrong answers"*. Dixit & Pindyck (1994) p. xi

The purpose of this chapter is not to provide the reader with a complete introduction to the theory of investment under uncertainty, but simply to provide the basic insight in order to obtain the necessary understanding for evaluating the implications for the access-pricing problem.

Traditional Net-Present-Value (NPV) analysis, used for evaluating investment projects, implicitly assumes certainty, reversibility, or that the investment decision is a now-or-never decision. The new theory of investment under uncertainty, also known as *real-option theory,* focuses on investment projects where these assumptions are not valid[128].

6.1 Investment characteristics justifying an option approach

6.1.1 Uncertainty

Most investments are made in an uncertain environment of changing prices, costs, demand and interest rates. Investors can only be sure of one thing: These parameters are either going to be higher or lower than expected. A rational investor needs to take uncertainty properly into consideration. Relying on average estimates, as regulators typically do, is a crucial mistake that may lead to wrong investment decisions. This is the main topic of this and the following chapter.

6.1.2 Irreversibility

Most investments are partially or completely irreversible in the sense that the initial cost can not be fully recovered in case it is decided to abandon the project. In other words, the costs are partially sunk. Either because they are simply "used" like e.g. investment in marketing, or

[127] The chapter is based on Dixit & Pindyck chapter 2,3,4,5 and 6

because the investment is firm- or industry-specific like e.g. training or investments in network infrastructure and therefore cannot be used for alternative purposes. Finally, even though a market for the used investment capital exists, costs are still likely to be partly sunk, because of the "lemon problem", described by Akerlof (1970)[129].

6.1.3 The option to wait

Firms do not always have an option to wait investing. Investing today may e.g. in some cases be necessary in order to pre-empt investment by a competitor. But often, an investment can be delayed. The combination of high sunk costs and a high degree of uncertainty about future revenues or costs makes it valuable to hold an option to delay an investment until some of the uncertainty has been resolved. In addition to postponing the investment decision, waiting allows the investor to adapt the investment to new information arriving from the market and from the regulator. Waiting is also associated with costs, though. Cash flows are foregone and other firms may enter. These costs must be balanced against the benefits of waiting for new information.

6.1.4 The option to invest

In an uncertain environment, an irreversible investment that may be postponed or never undertaken should be thought of as an "option to invest". Such an option may arise from a firm’s managerial resources, technological knowledge, reputation, market position, possible scale etc. - enabling the firm to productively undertake an investment that other firms may not be able to undertake. Such an option is valuable. Partly, because the investment may generate a present discounted value of future revenues that are higher than the present discounted value of future and initial costs. Partly, because the investment can also be made at a later date, extracting the value of new information arriving from the markets or the regulator.

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[128] Real option theory explores the value of a firm’s existing options (e.g. to postpone, contract or abandon a capital investment) and the value of building in options at some extra cost (e.g. the ability to switch between inputs or outputs, expand capacity, to default when investments are staged sequentially etc.).

[129] Sellers typically have superior knowledge to the buyer about the quality of the product. The buyer has to estimate the quality and may e.g. estimate the product to be of average quality. Buyers know that the seller will be reluctant to sell above-average-quality products for the average-quality price. When the buyer takes this into consideration he will lower his estimate of the quality and therefore also the price he is willing to pay. In other words: The fact that the seller is selling is seen as a sign of low quality. Akerlof used the market for "lemons" (used cars) as an example in his famous article "The Market for "Lemons": Qualitative Uncertainty and the Market Mechanism", Quarterly Journal of Economics, Vol. 84, Nov. 1970 pp. 488-500.

Such an option is in many respects similar to a financial "call" option, which gives the holder *a right but not an obligation* to buy a stock for a fixed "exercise price" at a later date[130]. The option to invest typically resembles an *American* call option, which gives you the right to buy the stock (to invest) at *any time* before a given future date[131].

When a firm, holding such an option to invest, invests, it incurs an alternative cost corresponding to the value of this option. The firm should therefore only invest if the discounted value of the future expected revenues, generated by the investment, minus the investment cost exceeds the value of the option to invest. The value of the option to invest is always non-negative: You can always refrain from investing. Traditional NPV-theory ignores the value of the option to wait. The following explores this in more detail. Before jumping to the more theoretical exposition, it is useful first to illustrate the main ideas and basic concepts based on a simple numerical example adapted from Dixit & Pindyck (1994).

6.2 Simple numerical examples illustrating main concepts and issues

6.2.1 Valuing the option to invest and the option to wait

Consider a firm trying to decide whether it should invest in a fibre optic cable. Assume that such an investment would allow the firm to produce one unit of data transmission per year. The investment is completely irreversible in the sense that the cable can only be used for data transmission. Assume that the cable can be built instantly at a cost I = €1600. The price of data transmission is currently €200 per unit. Next year with probability q this price will rise to €300 (say because of new value added services or scarce capacity) and with probability (1-q) it will drop to €100 (say because of increased competition from mobile data transmission). Afterwards the price will remain at the new level forever:

t = 0		t = 1		t = 2		
	$\xrightarrow{q}$	$P_1 = 300$	→	$P_2 = 300$	→	...
$P_0 = 200$						
	$\xrightarrow{(1-q)}$	$P_1 = 100$	→	$P_2 = 100$	→	....

[130] One should also keep in mind some of the differences between real options and financial options: 1) Stock options are exclusively owned whereas real options may often be shared with competitors. 2) Real options are generally not tradable, which may motivate early exercise to pre-empt competitors. 3) Real options are often interdependent.

For simplicity, we assume that the price of data transmission is fully diversifiable (unrelated to what happens with the rest of the economy). The firm should then discount future cash flows using the risk-free rate of interest, say 10 per cent. Set q to be 0.5 (in the next section we explore how the investment decision depends on q).

Should the firm invest now? We note that the expected future price of data transmission is (0,5*100 + 0,5*300) = 200. The Net Present Value of the described investment, using the standard way of calculating NPV, is:

$$NPV = -1600 + \sum_{t=0}^{\infty} \frac{200}{(1.1)^t} = -1600 + 2200 = €600 > 0$$

The investment has a positive NPV. According to standard investment theory, we should therefore go ahead and invest in the cable. That would be a mistake. Why? Because we have ignored a cost in the above calculation - the opportunity cost of investing now thereby foregoing the opportunity not to invest in case the price should fall.

To see this, we now calculate the NPV of holding an option to invest next period if the price rises, and abstain from investing if the price drops[132]:

$$NPV = (0,5)\left[\frac{-1600}{1.1} + \sum_{t=1}^{\infty} \frac{300}{(1.1)^t}\right] + (0.5)*0 = \frac{850}{1.1} = €773$$

If we postpone the investment decision to next year, the project *today* has a NPV of €773 as opposed to the NPV of €600 if instead we undertook the investment immediately. If we can postpone our investment decision, we should obviously do so. In case we did not have such an option, that is to say if the investment was a now-or-never decision, the investment should clearly be undertaken today since it has a positive NPV of €600.

In option terms: The firm is holding an "option to invest" worth €773[133]. Thus, the firm incurs an opportunity cost of €773 when it "kills"/exercises this option and invests today. The value of the "option to wait" can be calculated as the difference between the value of the option to invest and the value of investing today. In this example this value equals €773 - €600 = €173.

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[131] A *European* call option, on the other hand, gives you the right to buy a stock at a *specific* future date. A hybrid of the two options also exists: A *Bermuda* option, which you the right to buy at multiple specific future dates.
[132] To keep things simple, in this example only the price is uncertain.
[133] Here, we easily see that we would not gain from waiting beyond one period since the price remains the same thereafter. We would just forego €300 each period. More generally, we have to find the optimal time to invest.

For pedagogical reasons, it is appropriate to illustrate how the value of the "option to wait" is the sum of three components[134]:

1. Costs of foregone revenue: €200
2. Benefit form deferring the investment cost: 1600 - 1600/1.1 = €145.5
3. Benefits from avoiding the bad states: $(0.5)\left[\frac{1600}{1.1} - \sum_{t=1}^{\infty}\frac{100}{(1.1)^t}\right] =$ €227.3

Value of the option to postpone investment until next period: 227.3 + 145.5 - 200 = 172.8 ≅ €173

6.2.2 How increased uncertainty affects the value of the option to invest

Standard intuition tells you that increased uncertainty would reduce the value of an investment project. One of the most powerful insights of real-option theory is that increased uncertainty may actually *increase* the value of an investment project in the presence of managerial flexibility.

This can be illustrated with our simple example. Consider a mean-preserving increase in the variance. Assume as before that the price will rise or fall with an equal probability of 50 per cent but that the price now will rise or fall with 75 per cent instead of 50 per cent. Thus, the price will now either rise to €350 next year or drop to €150. The expected price remains at €200 but the value of the option to invest, when the project can be postponed, increases to

$$NPV = (0,5)\left[\frac{-1600}{1.1} + \sum_{t=1}^{\infty}\frac{350}{(1.1)^t}\right] + (0.5) * 0 = \frac{1125}{1.1} = €1023 > €773$$

And the value of the option to wait increases to €1023 - €600 = €423. The expected gain from investing now continues to be €600 but the value of the option to wait has increased. The cost of foregone revenues and the benefits of deferring the investment cost remain unchanged but the benefit of avoiding the "bad state" has increased.

Remember that the value of the option to invest has two components: 1) The value of discounted future cash flows exceeding costs and 2) The value of the option to wait. The values of the option to invest and the option to wait have both increased with €250. We may think of it in a slightly different way: The magnitude of the bad states as well as of the good states has been

[134] It is very simple but I have not seen it done elsewhere.

increased. But only the good states are realised. It is due to the asymmetric nature of the option (a right but not an obligation) that the value of the option to invest increases when uncertainty rises.

One might now get the wrong impression that it is the good states that are important for the investment decision. It is not! On the contrary, it is the magnitude and the probability of the bad state and *only* the bad state that affects the decision of whether to invest now or to wait. The magnitude of the good state is irrelevant. This is illustrated with a simple example in Dixit & Pindyck p. 40 but can also be explained verbally: If the price in the good state rises, all other things equal, the value of the investment project increases. But the decision between investing today or waiting is unaffected because the value of investing today and the value of investing tomorrow are equally affected. Whether you invest today or tomorrow you still receive the higher benefit if the world turns out to be in the good state. This can also be seen from the decomposition of the value of the option to wait, presented in section 6.2.1. The future good states enter the expression for investing today and next period in the same manner. The difference is the part of the expected value deriving from the bad state, which can be avoided. Dixit & Pindyck call this the "bad news principle" and it is useful to remember when considering how a given institutional set-up or change of variable will affect the investment decision.

When choosing the optimal investment time, the gain from waiting for more information to arrive from either the market, the technology or the regulator, has to be evaluated against the cost of delaying the investment (loss of first-mover advantage, foregone revenue etc). Trying to adjust the discount factor to take uncertainty into account is at best inadequate and may lead to wrong results as illustrated in the example, where the value of the option to invest increases.

6.2.3 Cost uncertainty and how uncertainty may also stimulate early investment

So far we have concentrated on revenue. We held constant quantity and considered uncertainty over the price. We could also have held the price constant and examined uncertainty over demand. But uncertainty over costs may be just as important. These could be costs of operation and in network industries especially the costs of establishing the network.

Let us now keep price and quantity constant/certain and examine the effect of uncertainty over the investment cost, I. Using the same example as above, the firm may have a fairly accurate estimate of the future demand/price for the use of its cable. But due to the rapidly changing technology, the future cost of establishing a link for telecommunications from A to B may be highly uncertain. What will be the cheapest kind of connection? Copper, fibre, satellite, wireless? What will be the price of equipment? What will be the cost of digging down the cable? Etc.

Assume like before that the investment cost of laying down the cable today is €1600. But next year it may increase to €2400 or decrease to €800, each with probability 0.5. Thus the expected price is €1600. Here we focus on cost uncertainty and keep the price certain at €200 forever and the interest rate certain at 10 per cent. Investing today has a NPV of

$$NPV = -1600 + \sum_{t=0}^{\infty} \frac{200}{(1.1)^t} = -1600 + 2200 = €600$$

Ex post though, it is optimally to invest only if costs fall. Thus, the value of the option to invest is

$$NPV = (0.5)\left[\frac{-800}{1.1} + \sum_{t=1}^{\infty} \frac{200}{(1.1)^t}\right] + (0.5) * 0 = \frac{700}{1.1} = €636$$

The option to invest has a value of €636 as opposed to the value of investing today, which equals only €600. The value of the option to wait thus equals €36 and the firm should wait. If the firm invested today it would forego the value of the €36, which could therefore be considered an extra (opportunity) cost of investing today. The €36 can also be thought of as the price that the firm would be willing to pay for the flexibility it has to postpone the investment decision until further information about future costs has arrived.

We have seen how uncertainty so far has increased the value of waiting until further information has arrived. The opposite would be true if the investment provided the firm with information that reduced uncertainty. Investing in the first cable e.g. may provide the firm with valuable information about costs as well as demand for its product. It is e.g. very difficult to estimate the demand for ADSL (broadband access via existing copper line) before it is possible to actually deliver ADSL to the customers. This is true for most innovative products. Construction costs may also be highly uncertain if you are the first to market the product.

We adapt our example to illustrate such an information structure: Suppose the price and the interest rate are still certain at €200 and 10% respectively. Let us first focus on cost uncertainty. We therefore continue to keep demand certain at unity. Suppose it initially costs €1000 to layout the core network. With a probability of 0.5, the network will be complete, but with the same probability we will need to spend another €3000 on the network to make it work. The expected investment cost of the network is therefore 1000 + (0.5)(3000) = 2500. The expected value of the project is €2200 as before. At first it might therefore appear that we should not invest in the project. This, however, would ignore the value of the information arriving next period. If we find out that the network will require an additional investment of €3000, we could simply close down the project[135]. Therefore the correct value of the option to invest is: -1000 + (0.5)(2200) = €100 > 0. We should go ahead and make the initial investment.

Instead of uncertainty over investment costs, we may introduce uncertainty over demand[136]. Suppose demand is 0.5 or 1.5 each with a probability of 0.5. This variance may be due to uncertainty over the average minutes per subscriber or alternatively due to uncertainty over the average take-up rate - the percentage of subscribers in the area. The new problem is that we can not observe whether demand is 0.5 or 1.5 until we have upgraded/built our network. Suppose we can invest in a network in two different areas at €2400 each. The price and the interest rate remain certain at 200€ and 10%. If we judge each investment opportunity separately or simultaneously we should not invest since the projects each have a NPV of

$$NPV = -2400 + (0.5)\sum_{t=0}^{\infty}\frac{0.5*200}{(1.1)^t} + (0.5)\sum_{t=0}^{\infty}\frac{1.5*200}{(1.1)^t} = -2400 + 550 + 1650 = -\text{ €}200$$

One might then think that we should not invest in either of the networks. Again this would be a mistake because we would be ignoring the value of the information arriving about demand when we have invested in the first network (we assume similar demand in the two areas). If we can postpone the investment decision about the second network until we have observed demand, the correct NPV of investing in the first network with the option to invest in the second is[137]:

$$NPV = -2400 + (0.5)\sum_{t=0}^{\infty}\frac{100}{(1.1)^t} + (0.5)\left[\sum_{t=0}^{\infty}\frac{300}{(1.1)^t} - 2400 + \sum_{t=0}^{\infty}\frac{300}{(1.1)^t}\right] = -2400 + 550 + 2100 = \text{€}250$$

We should invest in the first network, observe demand and then invest in the second network in case demand turns out to be high.

As these two examples show, increased uncertainty does not always favour postponement of the investment but may also encourage early investment if the investment provides valuable information that reduces uncertainty.

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[135] For simplicity we assume we can do that at no cost.
[136] This is my own example.

For an example of interest rate uncertainty see Dixit & Pindyck (1994) pp. 48-51.

6.3 Modelling uncertainty and the problem of pricing an option

The above examples were naturally oversimplified. Solving them may have seemed pretty obvious. That was the whole idea. The purpose was to sketch the consequences of viewing the investment decision as an investment option. In reality, though, uncertain values are rarely binomial distributed but take on a whole range of values. However, forecasting future cash flows correctly is not the key problem when valuing an option. The fundamental problem with traditional NPV-analysis is that we need a discount rate, the opportunity cost of capital, to discount these future cash flows. The problem with options is that the discount rate changes with the price of the underlying asset. For financial options this price could e.g. be the stock price. Here it is the value of the investment if made today. This value changes along with fluctuating prices, costs, and demand.

An option is said to be "in the money" when the value of the underlying asset is greater than the exercise price. For real options this corresponds to the case when the NPV of the now-or never-investment is larger than the investment cost. Similarly, it is said to be "out of the money" when the value of the underlying asset (the now-or-never-project) is less than the exercise price (the investment cost). An option which is "in the money" is safer than one which is "out of the money". An option is always riskier than the underlying stock (investment project)[138]. But the higher above the exercise price the value of the underlying asset is, the closer the risk of the option comes to the risk of the underlying asset. When the price of the underlying asset increases, the risk and thus the cost of capital decreases.

Finance experts have always known that the relevant variables for valuing options are the exercise price, the exercise date, the risk of the underlying asset and the interest rate. But they could not find the formula for putting these variables together in a usable formula. Finally, in 1973 Fischer Black and Myron Scholes came up with the answer on how to value an option[139]. They showed that the payoffs of an option could be copied by constructing a portfolio of an

[137] For simplicity we ignore the fact that the second network is built a little later than the first one and that the cash-flows therefore should be discounted slightly more than those of the first project.
[138] If this is not clear, think of investing one Euro in the option and one Euro in the stock.

investment in the underlying asset and borrowing. Since the portfolio would replicate the payoff of the option in all states, the value of such an option would have to be equal to the value of the portfolio. One could therefore avoid making the difficult risk-estimation and simply use the information provided by the market (i.e. the risk-free interest rate and the asset price). These techniques have later been refined in the financial literature and have recently been applied to the theory of investment in real assets[140].

It would be beyond the scope of the thesis to go into detail with option valuation. It will just be demonstrated how the option-value function can be found in a very general investment set-up in order to give the reader a basic understanding of the relationship between the value of the underlying asset - the now-or-never investment - and the value of the option to invest[141].

Suppose we can invest in a network that will generate a profit stream, π_t, and that this profit stream follows a geometric Brownian motion:

$$dp = a\,p\,dt + s\,p\,dz \qquad \text{, where } dz = e_t\sqrt{dt} \text{ and } e_t \sim N(0,1) \tag{6.1}$$

This may seem a restrictive assumption, and indeed it is. However, we have to come up with some way of modelling the uncertain revenue and this is a very general one. E(dz) = 0, which means that $E(d\pi) = \alpha\,\pi\,dt$. The expected percentage change of π, $E(d\pi)/\pi$, equals $\alpha\,dt$. Therefore α is the expected growth rate of π per period, which may be negative, thus, expressing falling expected revenues due to increasing competition and lower prices. π could also simply be set at 0 if our best estimate of future revenues were that they would remain unchanged. The more interesting part of the expression is the second part, which models uncertainty.

The profit stream π is expected to increase with α per cent over the next period but we know that it may be more or less. The variance of $d\pi$ is $var(d\pi) = \sigma^2\pi^2\,dt$ [142]. We note that the variance of the change grows linearly with the time horizon, which seems intuitive. The longer the period, the larger the uncertainty over π[143].

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[139] Black & Scholes, "The Pricing of Options and Corporate Liabilities", Journal of Political Economy Vol. 81, pp. 637-654.

[140] Dixit & Pindyck (1994) were the first to give a comprehensive presentation of real-option theory and their book "Investment under Uncertainty" is still "the bible" within this area.

[141] Another motivation: Presumably, only few readers - even economists - are familiar with real-option valuation.

[142] $Var(dz) = E((dz)^2) - (E(dz))^2 = dt$ since $dz = e_t\sqrt{dt}$ and $e_t \sim N(0,1)$

[143] Whether it should be exactly linear can be questioned but is seems just as reasonable as anything else and it is the standard assumption in real-option theory. Actually we would not be able to solve the math without this assumption.

6.4 Real-option valuation and the optimal investment rule[144]

6.4.1 Estimating the cost of capital

Before we can use option pricing, we need to make one important assumption about the stochastic changes in π. They have to be *spanned* by existing assets in the economy: There needs to be a traded asset or a portfolio of traded assets, on which the return is perfectly correlated with the return on our investment, π[145]. This assumption holds for all financial assets and for assets traded on spot and future markets. However, it is less likely to hold for a new product that is unrelated to any existing assets. This may pose a problem when applied to a framework of investments in network infrastructure. But first of all, another method exists: dynamic programming (see appendix B) - a method that does not require existence of spanning assets. Secondly, establishing the appropriate cost of capital/discount rate for a capital investment is just as big a problem for conventional (NPV) investment theory. Finally, the point of this chapter is not to calculate an exact value, but simply to illustrate the methodology and to show how important an effect uncertainty may have on the optimal investment rule.

The cost of capital is found by the capital asset pricing model (CAPM), according to which the cost of capital, μ, can be found as:

$$\mu = r_f + \phi\ \sigma\ \rho_{\pi m} \qquad (6.2)$$

r_f is the risk-free interest rate, given by the market. $\phi=(r_m-r_f)/\sigma_m$ corresponds to the market price of risk, also given by the market. And $\rho_{\pi m}$ is the coefficient of correlation between the returns of our investment, π, (or the replicating portfolio) and the market portfolio[146] [147]. What matters to investors is *undiversifiable risk* - risk that can not be eliminated by holding a diversified portfolio. This risk depends on the volatility of π and the extent to which this volatility is

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It is used to motivate the smooth pasting condition, described below an illustrated in figure 6.2. Here dz's dependence on the square of dt is used.

[144] This is also referred to as "contingent claims analysis".

[145] This is a very strong assumption. Not only should it have the same mean and variance, it should replicate the movements of π in all possible states.

[146] CAPM is the predominant method for estimating the cost of capital. It has been declared "death" several times but as Brealy & Myers (2000) note: "Only a strong theory can survive several funerals". (p.201).

[147] CAPM is typically presented in a rewritten manner as $\mu = r_f + \beta(r_m-r_f)$. Where β (beta) = $\sigma_{\pi m}/\sigma_m^2$ expresses how much the price of the asset (on average) changes when the price of the market portfolio rises 1%. r_m is the return on the market portfolio.

correlated with the market portfolio[148]. If π is uncorrelated with the market portfolio, the entire risk can be diversified away by investors. CAPM then predicts the cost of capital to be equal to the risk-free interest rate[149]. σ represents the per-period standard deviation on the return (see eq. 6.1). Given this, the price of the asset has to adjust in order for the expected return to equal μ.

6.4.2 Valuing the project

Let $V(\pi)$ denote the value of the (completed) investment project. $V(\pi)$ is the present value of future expected revenues. Throughout, we work within a continues-time framework. The expected value of π_t, when $d\pi$ is given by (6.1), is $E[\pi_t] = \pi_0 e^{\alpha t}$. $V(\pi)$ is then found by discounting the expected future revenues by the appropriate discount rate, μ, found by CAPM[150]:

$$V(p_0) = \int_0^\infty p_0 e^{at} e^{-mt} = \frac{p_0}{(a-m)}\left[e^{(a-m)t}\right]_0^\infty = \frac{p_0}{a-m}(0-1) = \frac{p_0}{m-a}$$

We have assumed $\mu > \alpha$. If $\mu < \alpha$, V would be infinitely large.

In the above formula for $V(\pi_0)$ we have ignored depreciation. Suppose instead that the investment deteriorates exponentially with a factor λ, so it will generate only $\pi_0 e^{-\lambda t}$ in period t instead of π[151]. Then $V(\pi_0)$ is found as:

$$V(p_0) = \int_0^\infty (p_0 e^{-lt}) e^{at} e^{-mt} = \frac{p_0}{(a-m)}\left[e^{(a-m-l)t}\right]_0^\infty = \frac{p_0}{a-m-l}(0-1) = \frac{p_0}{m-a+l}$$

Thus, $V(\pi)$ is a multiple of π, following therefore the same geometric Brownian motion as π (equation 6.1). Though this may be quite obvious, it is of interest to demonstrate that it is indeed true, since the property is used later[152]:

$d\pi = \alpha\pi dt + \sigma\pi dz$ and $V = k\pi \Rightarrow$

[148] In theory the market portfolio consists of all risky assets, national as well as international. In practice the national stock market index is typically used - as a proxy or due to ignorance.
[149] Empirical data suggest that CAPM underestimates the required return (cost of capital) for assets with low market correlation (low beta) and overestimates the required return for assets with high correlation with the market (high beta). See Brealy & Myers (2000) for more on CAPM, risk, and the required return on capital.
[150] We implicitly rule out speculative bubbles. For more on that see Dixit & Pindyck (1994) pp. 179-182.
[151] Similar results would be obtained if instead we assumed a random lifetime of the project in such a way that the project had a probability λdt of dying (being obsolete) during the next period. For more on depreciation see Dixit & Pindyck (1994) pp.199-207
[152] Not shown in Dixit & Pindyck.

$$dV = k\,d\pi = k(\alpha\pi dt + \sigma\pi dz) = \alpha(k\pi)dt + \sigma(k\pi)dz = \alpha V dt + \sigma V dz \qquad \text{Q.E.D.} \qquad (6.3)$$

6.4.3 Valuing the option to invest in the project and the optimal investment rule

Let F(V) denote the value of the *option* to invest in our project, keeping in mind that V was the value of the undertaken project. To find this value function, we construct a portfolio of one option to invest and a *short position*[153] of n units of the project (or of an asset or portfolio of assets, which generates revenue perfectly correlated to π) [154]. Now consider holding this portfolio over the small time interval (t, t + dt):

Since we hold an option and not the actual project, we obtain no revenue. On the other hand, for each unit of the short position, we will have to compensate the investor who holds the corresponding *long position*[155] for his loss associated with not holding the asset in the period. He will demand the risk-adjusted return, $\mu V dt$, which equals the capital gain, $\alpha V dt$, plus a dividend stream/convenience yield of $\delta V dt$, where $\delta = \mu - \alpha$[156]. The investor with the long position is automatically compensated for the capital gain because he has a claim on the asset for a fixed price. What we will need to pay him is therefore $\delta V dt$. Thus, our portfolio yields a net dividend of $-n\delta V dt$. But it also yields a (stochastic) capital gain of dF - n dV: The option to invest will be worth more next period if π and consequently V increases. We also lose if V increases, though, because we are short in the basic asset and therefore have to buy it in the market in the future.

F is a function of V, and we know the stochastic process of V. We can then use *Ito's lemma*[157] to find dF:

$$dF(V) = F'(V)dV + \tfrac{1}{2}F''(V)(dV)^2 \quad + 0\,(dV)$$

The total return from holding the portfolio is:

$$dF - n\,dV - n\,\delta\,V\,dt = F'(V)dV + \tfrac{1}{2}F''(V)(dV)^2 - n\,dV - n\,\delta\,V\,dt$$

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[153] "Short" means that we have promised to sell the good in the future without yet owning it.

[154] To do this in practice, either the product needs to be traded or we should be able to construct a portfolio of traded assets that replicate the volatility of π.

[155] This investor has bought and paid for the asset but has not received it yet.

[156] If V were the price of a stock, δ would be the dividend rate. For a physical good it represents the flow of benefits that the marginal stored unit provides. δ is an opportunity cost of delaying the construction of our project and instead keeping the option to invest (or rather not invest) alive; just like foregone dividend is an opportunity cost of holding a call option on a stock instead of holding the stock itself.

[157] Ito's Lemma states that if F is function F(x,t), then dF = $\frac{\partial F}{\partial t}dt + \frac{\partial F}{\partial x}dx + \frac{1}{2}\frac{\partial^2 F}{\partial x^2}(dx)^2$. Here F is independent of t. Therefore the first term is omitted. Fore more on Ito's Lemma see Dixit & Pindyck (1994) pp. 79-82.

$$= [F'(V) - n]\ dV + \tfrac{1}{2}F''(V)(dV)^2 - n\ \delta\ V\ dt$$

We then insert dV and use that $E[(dV)^2] = E[\alpha^2V^2(dt)^2 + \sigma^2V^2(dz)^2 + \alpha\sigma dtdz] = \sigma^2V^2dt$. The latter is true because terms which include dt in a higher order than 1 are eliminated when $dt \rightarrow 0$ and because $E[dtdz]=dt^{3/2}$ and $E[(dz)^2] = dt$.

$$[F'(V) - n]\ (\alpha Vdt + \sigma Vdz\ ) + \tfrac{1}{2}F''(V)\ \sigma^2V^2dt - n\ \delta\ V\ dt$$

We note that only the first term involves uncertainty (dz). We then apply the key trick of option pricing: We choose $n = F'(V)$, thereby eliminating the first term. The return on our portfolio now becomes risk-free. To avoid arbitrage possibilities, the return per period should equal the return on a risk-free asset with the same value as our portfolio, which is $F(V) - nV = F - F'(V)V$:

$$\tfrac{1}{2}F''(V)\ \sigma^2V^2dt - F'(V)\ \delta\ V\ dt = r_f\ \ [F - F'(V)V]\ dt$$

By dividing through with dt and rearranging we get:

$$\tfrac{1}{2}F''(V)\ \sigma^2V^2 + (r_f - \delta)\ F'(V)\ V - r_f\ F = 0 \qquad (6.4)$$

This is the differential equation that F(V) must satisfy in order to avoid arbitrage possibilities. We must also have:

$$F(0) = 0 \qquad (6.5)$$

From the stochastic process of V, given by equation 6.3 (6.1), we know that if V = 0, V will remain 0 forever (0 is said to be an *absorbing barrier*). Thus the option to invest will have to be worthless. 6.5 is a *boundary condition*.

To satisfy the differential equation (6.4) and the boundary condition (6.5), F(V) must take the form of:

$$F(V) = AV^{\beta} \qquad (6.6)$$

To find the solution, we insert (6.6) and its derivatives into (6.4) and divide through with AV^{β}:

$$\tfrac{1}{2}\beta(\beta-1)AV^{\beta-2}\ \sigma^2V^2 + (r_f - \delta)\beta AV^{\beta-1}\ V - r_f\ AV^{\beta} = 0 \qquad \Leftrightarrow$$

$$\tfrac{1}{2}\beta(\beta-1)AV^{\beta}\sigma^2 + (r_f - \delta)\beta AV^{\beta} - r_f\ AV^{\beta} = 0 \qquad \Leftrightarrow$$

$$\tfrac{1}{2}\beta(\beta-1)\sigma^2 + (r_f - \delta)\beta - r_f\ = 0 \qquad \Leftrightarrow \qquad (6.7a)$$

$$\tfrac{1}{2}\sigma^2\beta^2 + (r_f - \delta - \tfrac{1}{2}\sigma^2)\beta - r_f\ = 0 \qquad (6.7b)$$

We see that $F(V)=AV^{\beta}$ is a solution to the differential equation (6.4) provided that β is root in equation (6.7a/6.7b).

The two roots are:

$$b_1 = \frac{-(r_f - d - \frac{1}{2}s^2) + \sqrt{(r_f - d - \frac{1}{2})^2 + 4\frac{1}{2}s^2 r_f}}{s^2} = \frac{1}{2} - \frac{r_f - d}{s^2} + \sqrt{\left[\frac{r_f - d}{s^2} - \frac{1}{2}\right]^2 + \frac{2r_f}{s^2}} > 1$$

$$b_2 = \frac{-(r_f - d - \frac{1}{2}s^2) - \sqrt{(r_f - d - \frac{1}{2})^2 + 4\frac{1}{2}s^2 r_f}}{s^2} = \frac{1}{2} - \frac{r_f - d}{s^2} - \sqrt{\left[\frac{r_f - d}{s^2} - \frac{1}{2}\right]^2 + \frac{2r_f}{s^2}} < 0$$

Therefore, the general solution to our differential equation (6.4) is:

$$F(V) = A_1 V^{\beta_1} + A_2 V^{\beta_2}$$

The left-hand side of (6.7a) is called "the fundamental quadratic". We denote it $Q(\beta)$ and draw it:

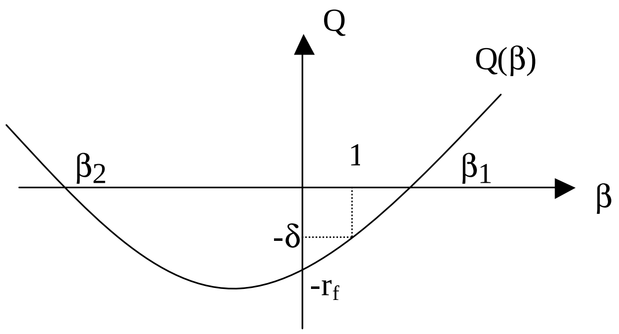

Figure 6.1 - The fundamental quadratic

From equation 6.7a, we see that $Q(1) = -\delta < 0$ (by assumption $\delta = \mu - \alpha > 0$) and $Q(0) = -r_f < 0$. From figure 6.1, we can now conclude that $\beta_1>1$ and $\beta_2<0$.

The boundary condition (6.5) implies that $A_2 = 0$. Otherwise F(V) would approach ∞ when V went to 0.

We are now left with the solution for our option value, F, as a function of V:

$$F(V) = A_1 V^{\beta_1} \tag{6.8}$$

where A_1 remains to be determined. To find A_1 and V*, the level of V at which it will be optimal to invest, we invoke a *value-matching condition* (6.9) and a *smooth-pasting condition* (6.10):

$$F(V^*) = V^* - I \tag{6.9}$$

$$F'(V^*) = V' = 1 \tag{6.10}$$

Equation 6.9 is very intuitive: When it is optimal for a firm to invest, the value of exercising the option must equal the value of holding the option. The value of exercising the option equals the value of the investment, V^*, minus the investment cost, I. If the option value were greater than the net value of investing, the firm should keep the option alive instead of investing. If on the other and, the option value were below the net value of investing, the firm should have invested earlier.

The explanation of the smooth-pasting condition (6.10) is more technical and requires a graphical illustration:

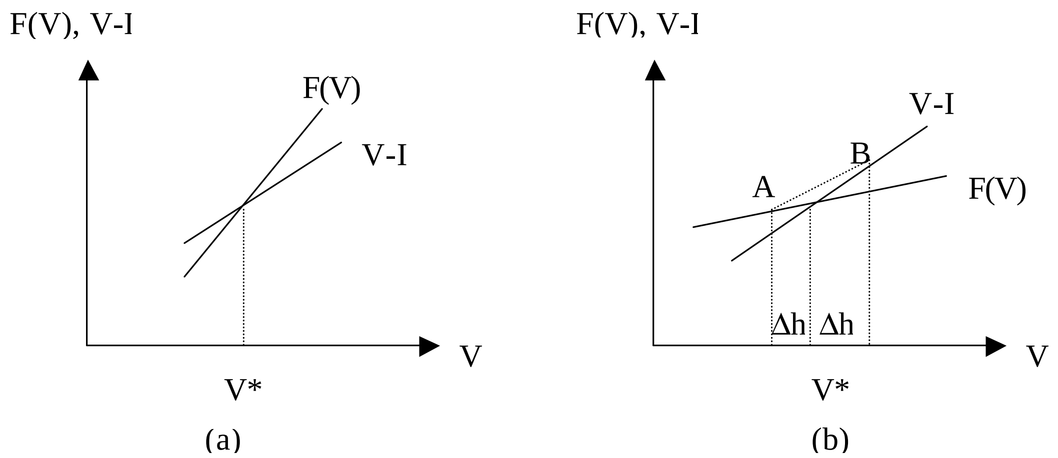

Figure 6.2 - The smooth-pasting condition

Suppose we have F' > V' as illustrated in figure 6.2 (a). Assume that V* is indeed the revenue stream that triggers investment. Due to the investment set-up, where the cost of waiting (foregone revenue) increases with V, we know that V* should be such that we invest for V ≥ V*. Therefore it is easy to rule out situation (a) since, by continuity, the option value would be greater than the value of the investment if V were just slightly greater than V*. For V'>V* we have F(V') > V'-I. We should then keep our option alive and not invest, contradicting the rule to invest when V ≥V*. Also we should have invested already for lower values of V since V'-I > F(V') for V'<V*.

It is slightly more complicated to rule out situation (b). Here is the intuition: Suppose we are at V=V*. By waiting a little bit longer, V will be either a little bit larger or a little bit lower than V* so that we will be in point A or point B. The average (situated on AB) will be greater than F(V*)=V*-I. However, this expected payoff should be discounted because we receive it next period instead of this period. But we only discount with a factor proportional to Δt, while the steps upwards and downwards in V, Δh - and therefore in the value of the expected payoff - are proportional to the *square* of Δt. This property is due to the fact that V is assumed to follow a Brownian motion (remember that $dz = e_t\sqrt{dt}$). For Δt small, the square of Δt is *larger* than Δt. If we wait one period, the expected value increases with a factor greater than it is discounted with. We would therefore gain from waiting, which contradicts that V* is the value that triggers investment. For more on smooth pasting, see Dixit & Pindyck (1994) chapter 3, appendix C[158].

We now insert our F(V) in the value-matching condition (6.9) and in the smooth-pasting condition (6.10):

$$F(V^*) = A_1 V^{*\beta_1} = V^* - I \quad \Leftrightarrow \quad \beta_1 A_1 V^{*\beta_1} = \beta_1(V^* - I) \qquad (6.9b)$$

$$F'(V^*) = \beta_1 A_1 V^{*(\beta_1-1)} = 1 \Leftrightarrow \beta_1 A_1 V^{*\beta_1} = V^* \qquad (6.10b)$$

Because the two left-hand sides of (6.9b) and (6.10b) are identical, we have:

$$V^* = \beta_1(V^* - I) \quad \Leftrightarrow \quad V^* = \frac{b_1}{b_1 - 1} I \qquad (6.11)$$

We do not really need A_1, but for the record it can be found by inserting (6.11) into (6.9b):

$$A_1 = \frac{V^* - I}{V^{*b_1}} = \frac{\frac{b_1}{b_1-1} I - \frac{(b_1-1)}{b_1-1} I}{\left(\frac{b_1}{b_1-1} I\right)^{b_1}} = \frac{I(b_1-1)^{-1}}{I^{b_1}(b_1-1)^{-b_1} b_1^{b_1}} = \frac{(b_1-1)^{b_1-1}}{I^{b_1-1}(b_1)^{b_1}} \qquad (6.12)$$

With (6.8), (6.11) and (6.12) we have found the value of the option to invest F(V) and the optimal investment rule: invest when V ≥ V* where V* is determined by (6.11). For V > V* the firm invests and F(V) equals V-I. The correct expression for F(V) is therefore:

158 If you do so, note that the case presented here is the "opposite" case of that presented by Dixit & Pindyck. They illustrate smooth pasting in a set-up where it is optimal to stop (invest) for values of the stochastic variable *smaller* than the optimal level.

$$F(V) = \begin{cases} A_1 V^{b_1} & for\ V < V^* \\ V - I & for\ V \geq V^* \end{cases} \qquad (6.13)$$

Figure 6.3 below illustrates the investment problem:

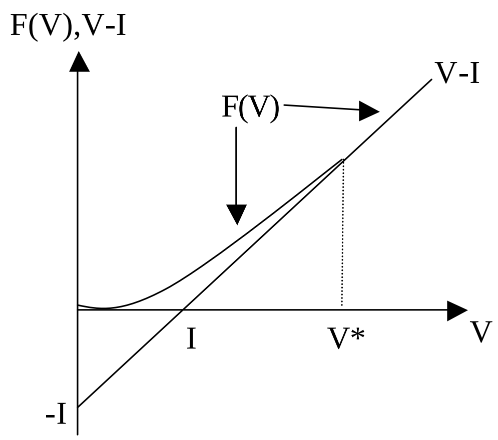

Figure 6.3 - The optimal investment rule

(6.11) is the key equation. Given our assumption that $\mu > \alpha$, we know that $\beta_1 > 1$ (see figure 6.1 of the quadratic equation). Therefore $\beta_1/(\beta_1-1) > 1$. This in turn implies that V* > I as illustrated in figure 6.3. Thus, in a world of uncertainty and irreversibility, the neo-classical investment rule: "Invest when NPV = V-I ≥ 0" is incorrect if the firm has the managerial flexibility to postpone the investment decision[159]. The firm will require V to be sufficiently larger than I in order to compensate it for its opportunity cost associated with "killing" its option to invest, thereby foregoing the possibility of waiting for more information to arrive. As explained earlier, holding on to this option is valuable 1) Because the firm can still invest and 2) Because the firm can avoid investing in case the state of the world turns out less favourable. Only when the current revenue, and thereby V, becomes so large that foregone revenue of not investing exceeds the opportunity cost of investing will the firm invest.

[159] Even in a deterministic world where $\sigma=0$, V* will be larger than I if $\alpha>0$ and I remains constant. This is because the future investment cost, I, is discounted at μ, while the future value is discounted at only μ-α, because the value of the investment, V, increases by α per cent each period. In present value terms, I therefore decreases more than V when the investment is postponed. It is easy to show that F(V) and V* increases when α increases and that $V^* = (\mu/\mu-\alpha)I > I$ (see Dixit & Pindyck pp. 138-39). For the same reasons there will also be a value to waiting (V* will be larger than I) if I is falling at a faster rate than V.

Let us formally investigate the effect on the ratio $\beta_1/(\beta_1\text{-}1)$ when uncertainty (σ) is increased: Go back to the fundamental quadratic Q(β), which is the left hand side of (6.7a) and which is illustrated in figure 6.1:

$$Q(\beta) = \tfrac{1}{2}\beta(\beta\text{-}1)\sigma^2 + (r_f - \delta)\beta - r_f = 0$$

Differentiate this expression totally:

$$\frac{\partial Q}{\partial b}\frac{\partial b_1}{\partial s}+\frac{\partial Q}{\partial s}=0\,,$$

where all derivatives are evaluated at β_1. From the quadratic equation we see that $\partial Q/\partial s = s \; b(b-1) > 0$ (evaluated at β_1>1) . And from figure 6.1 we know that $\partial Q/\partial b > 0$ at β_1. Therefore, $\frac{\partial b_1}{\partial s} < 0$. And when β_1 decreases, $\frac{b_1}{b_1 - 1} = \frac{1}{1 - 1/b_1}$ increases. Hence, we can conclude that increased uncertainty (increased σ) increases the wedge between V* and I[160].

Considering this wedge, it is very important to understand that if society is facing the same costs as the firm, it is also optimal for society to postpone the investment until V=V*[161]. The $\beta_1/(\beta_1\text{-}1)$ factor has nothing to do with the monopoly mark-up, where a monopoly uses its market power to limit production and raise the price. Here, the firm does not choose production or price. We take those as given by nature and focus on the investment decision.

Dixit & Pindyck show that the same wedge will apply in a competitive industry[162]. The only, but important, difference is that in the competitive framework the value of the option to invest (wait) is competed away. In the monopolistic set-up, considered here, the option to invest provides the monopolist with economic rent; the value of waiting is not competed away.

Evaluating the situation of oligopoly in our stochastic dynamic setting raises tremendous problems due to the scarcity of tractable models in stochastic game theory. The problem is that the oligopolistic firm incurs an additional cost of waiting: the cost of risking pre-emption by a rival. If there is only room for one firm, the firm loses the entire value, V-I. If there is room for

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[160] Some limit results: As α approaches infinity, $\beta_1 \rightarrow 1$ and $V^* \rightarrow \infty$. What happens when $\sigma \rightarrow 0$ depends on α: If $\alpha > 0$, then $\beta_1 \rightarrow \mu/\mu\text{-}\delta$ and $V^* \rightarrow (\mu/\delta)I$ (see also the previous footnote). If $\alpha \leq 0$, then $\beta_1 \rightarrow \infty$ and $V^* \rightarrow I$.

[161] A social planner has no better knowledge about the future than the firm has. Upon investment, a social planner therefore incurs the same opportunity cost of "killing" the option to invest/wait. A social planner will weigh foregone utility to consumers against the benefit of waiting for more information to avoid uneconomic investments.

[162] Dixit & Pindyck (1994) chapter 8.

multiple firms, the firm loses its first-mover advantage. Whether the option value of waiting or the fear of pre-emption dominates, depends on the parameters[163].

The above results have been derived for π following a Brownian motion. However, similar but much less tractable formulas/results can be found with other specifications of uncertainty such as mean-reverting processes or Brownian motions combined with jump processes (see Dixit & Pindyck pp.161-173). It would be beyond the scope of this thesis to evaluate these different specifications.

Before turning to the application of the described real-option theory to the access-pricing problem, let us finish by evaluating the investment rule again, now in terms of the revenue, π. In the above we went through the calculations using V because we had shown that V followed the same stochastic process as π. Now we reintroduce the underlying variable π in order to compare, once again, our investment rule with the traditional (Marshallian) rule of investment.

Remember that $V(p_t) = \frac{p_t}{m - a + l}$. Therefore, the rule: invest when $V_t \geq V^* = \frac{b_1}{b_1 - 1} I$, is equal to

$$\pi_t \geq \pi^* = \frac{b_1}{b_1 - 1}(m - a + l)\, I > (m - a + l) I$$

The last term is Long Run (Average) Incremental Costs[164]. Remark: Throughout the analysis we have ignored variable costs for simplicity because they only change the problem when production can be temporarily shut down. The latter is not particularly relevant in network industries like telecom, electricity and gas. Absent the possibility to temporarily shut down production, variable costs/operating costs, C, would just be added to the cost expression linearly - assuming that they were not associated with uncertainty[165]:

$$\pi_t \geq \pi^* = \frac{b_1}{b_1 - 1}(m - a + l)\, I + C > (m - a + l) I + C$$

We see that a revenue stream equivalent to LR(A)IC is not enough to make the company willing to invest because it does not compensate the firm for the opportunity cost associated with "killing" its option to invest.

[163] Dixit & Pindyck (1994) present a specific two-firm model pp. 309-314.
[164] *Incremental* in the sense that we considered an investment which generated only one unit of output. To produce the unit we need to undertake the entire investment. If the investment generated two units, LRAIC would be halved.
[165] For more on operating costs and the possibility of temporary suspension see Dixit & Pindyck (1994) pp. 186-195

Chapter 7

Applying real-option theory to the question of access pricing[166]

After the brief introduction to real-option theory in chapter 6, we are now ready to evaluate the extend to which this new way of thinking about investments may apply to access pricing, and if so, discuss the implications for the regulated access price compared with LR(A)IC.

First we must consider whether real-option pricing is in fact relevant. For this to be the case, we must be dealing with an investment problem characterised by uncertainty, irreversibility and managerial flexibility to postpone (or modify) the investment. The following section investigates the applicability of these assumptions.

7.1 The assumptions justifying a real-option approach

7.1.1 Uncertainties

A network operator faces at least 5 different, though to some extent related, types of uncertainty:

1. *Technological u.*: (When) will a new substituting more cost-effective technology appear, making the operators network redundant or less profitable? (In telecom e.g. these technologies could be fibre-, packet switching-, mobile-, satellite, cable technologies etc.)

2. *Market u.*: Will there be entry? What will the entrant's costs and prices be? Etc. These questions may depend on the technological as well as the regulatory development.

3. *Demand u.*: How large will the demand for the services provided via the network be? This depends on the market situation, consumer preferences as well as substituting technologies. It is

[166] The idea of applying real-option theory to the access-pricing problem was discussed at a seminar held at Columbia University on 2 October 1998. The first record I have found of it, is a written testimony by Jerry Hausman from 1996. He used the real-option approach in a legal testimony to critique the use of TSLRIC prices for unbundled elements in telecom in the US (reply affidavit of Jerry A. Hausman, in the matter of Implementation of Local Competition Provisions in the Telecommunications Act of 1996, CC-Docket No. 96-98, May 30, 1996 (Hubbard and Lehr, 1996)). The formalisation of the problem including the presentation of Dixit & Pindyck in the previous chapter and many of the thoughts presented in this chapter are my own. A book, edited by James Alleman and Eli Noam, called "The Investment Theory of Real Options and its Implications for the Telecommunications Network" has been published in December 1999, Kluwer (2000). I have not seen the book but I have found three of the papers presented in the book (Alleman (1999), Hausman (1999), and Economides (1999). None of these papers provide a formalised presentation of the problem as presented in this and the previous chapter.

difficult, for example, to estimate how many subscribers will switch to ADSL technology for Internet access. It may also be difficult to estimate how many will take up cable-TV etc.

4. *Regulatory u.:* Will the current regulatory regime remain? Will regulators unbundle certain elements of the network? Will LR(A)IC principles be used? And even if this is known with certainty, what price will the LR(A)IC-model come up with?

5. *Interest rate u.*: This applies to all investments and will not be discussed further here[167].

The type and the degree of uncertainty vary substantially from industry to industry and from one network element to another. They will have to be evaluated on a case-by-case basis.

7.1.2 Irreversibility

Network industries are characterised by large sunk capital-intensive investments in infrastructure (pipes, wires, trenches, ducts, switches, buildings etc.). It is very costly to lay down a network and when in place, it is very difficult to use it for other purposes. The degree of irreversibility varies from industry to industry and from network element to network element. Irreversibility therefore has to be evaluated on a case-by-case basis, even though it is generally safe to characterise investments in network infrastructure as irreversible.

7.1.3 Managerial discretion/the option to wait

Whether a firm has an option to wait constructing, expanding or upgrading a network depends on the competitive situation it faces. Investment in infrastructure, however, requires large amounts of capital and incumbents have substantial advantages compared to entrants due to their pre-existing network and experience. Therefore, it seems reasonable to assume some discretion over the investment decision and thus, the existence of an option to wait. An entrant, facing a decision between renting or building infrastructure, certainly holds such an option to wait building his own network and rent capacity from the incumbent in the mean time.

[167] One interesting insight of Dixit & Pindyck (1994) is worth mentioning, though. Based on their analysis, Dixit & Pindyck conclude that interest rate *volatility* is typically much more important for investment behaviour than is the interest rate *level*, and that public policy, intended to stimulate investment, should focus more on the *stability* of interest rates rather than the *level* of interest rates. See Dixit & Pindyck pp. 48-51.

7.2 Investment under uncertainty and price regulation

7.2.1 The optimal investment rule for a regulated firm facing uncertain demand

Dixit & Pindyck's results on the existence of option premiums, presented in chapter 6, holds when π follows the stochastic process described in equation 6.1 - a Brownian motion[168]. Dixit & Pindyck focus on price uncertainty as causing the uncertainty over revenue but they also evaluate uncertainty over operating costs, investment costs and the interest rate.

When dealing with a regulated firm, however, it may be problematic to assume that prices fluctuate according to a Brownian motion since the price is typically subjected to a price-cap (described in chapter 5). This is one of the reasons why one of the most general ways to specify uncertainty was chosen in the previous chapter: uncertainty over revenue, π, or over the entire project value, V. Even if the firm (correctly or not) considers the price, given by the regulator, to be certain, the uncertainties described above still cause substantial uncertainty over future revenue, π.

Using the most simple set-up possible, consider e.g. a firm facing a regulated (certain) price, P', on its product, network transmission. Variable costs, C, are assumed to be constant[169]. Assume now that the firm faces uncertain demand, X, following a geometric Brownian motion: $dX = \alpha\, X\, dt + \sigma\, X\, dz$.

Because (P'-C) is constant, π = [(P'-C) X] follows the same geometric Brownian motion as X does[170]. For a given level of demand (or rather expectation of demand), X', suppose that the regulator sets P' in order for π to cover the firms long run average incremental costs, which are found such that $(P'-C)X' = (\mu-\alpha+\lambda)\, I$. That is $P' = \frac{(m - a + l)I}{X'} + C$, which compares to basic LR(A)IC prices.

Already here, we note a few things regarding LR(A)IC-based prices. First, if demand is expected to fall ($\alpha<0$), say due to entry, this should be incorporated in a higher regulated price. Second, prices should be adjusted (upwards) to compensate the firm for economic depreciation. This economic depreciation do not need to correspond to physical deterioration of the network

[168] As mentioned earlier, similar but less tractable results can be found with other specifications of uncertainty such as mean reverting processes or Brownian motions combined with jump processes (see Dixit & Pindyck pp.161-173).
[169] This does not contradict the assumption of economies of scale/density. Remember that we keep the investment cost I constant. Thus, an increasing number of customers do lower average costs.
[170] This property was demonstrated in chapter 6.

but should also reflect technological development and falling capital input prices for competitors. Regardless of the price regulation, the incumbent may have to lower his prices in the future in order to compete with entrants facing superior or cheaper technology (a lower I). In order to provide the incumbent with efficient investment incentives, the price needs to incorporate these expectations about demand and deterioration.

More interestingly, real-option theory here tells us that even if the firm is compensated for these expected changes in demand and economic depreciation through the regulated price, P', the firm will not be willing to undertake the investment at this price if 1) The firm has an option to wait and 2) The investment is irreversible. This is because the firm can gain from postponing its investment decision in order for some of the uncertainty over demand to be resolved. In our simple set-up, the firm will choose not to invest until:

$$p(X) = (P' - C)X = \left(\frac{(m - a + l)I}{X'} - C + C\right)X \geq \frac{b_1}{b_1 - 1}(m - a + l)I \Leftrightarrow X > \frac{b_1}{b_1 - 1}X'$$

where X' is the demand expected by the regulator and incorporated into P'. Here, demand is the uncertain variable. But uncertainty could also be modelled for I, P' or C.

7.2.2 Welfare implications

So what are the welfare implication of this? If consumers' willingness-to-pay equals the regulated price, P', then it would actually be in society's best interest to wait until some of the uncertainty is resolved, just like the regulated firm would do. The outcome would be the same as absent regulation. From society's point of view, the option to wait is just as valuable as it is to the firm so a social planner would take uncertainty and irreversibility into account just like the firm does.

However, the problem is that consumers' willingness to pay is often much higher than the regulated price/the cost of provision. When choosing whether to postpone an irreversible investment due to uncertainty, the firm only considers foregone revenue whereas a social planner should consider foregone consumer surplus as well. If consumers' willingness to pay is higher than the price observed by firm and the firm decides to postpone an investment, that otherwise would have been undertaken, society incurs a welfare loss because the regulated firm is not provided with proper investment incentive.

On the other hand, if the price was not regulated at all, the firm would be tempted to charge an excessive price, higher than the one required for undertaking the investment. We therefore have a (potential) conflict between static allocative efficiency and dynamic investment efficiency. Static allocative efficiency requires p = MC, while dynamic investment efficiency requires an additional reasonable compensation to the firm for fixed costs - incorporated in LR(A)IC - *as well* as a compensation for "killing" its option to invest, foregoing the possibility of waiting for more information about uncertain variables - not incorporated in LR(A)IC.

7.2.3 The entrant's option and the "make-or-buy"-decision

Let us now turn to the entrant, who faces a choice between renting infrastructure from the incumbent or building his own infrastructure. First we concentrate on costs and ignore strategic considerations for a second.

If the entrant builds his own network, he receives the revenue π but incurs a cost per period of LR(A)IC, assuming that LR(A)IC reflect true costs. If instead the entrant decide to buy/rent the equivalent capacity from the incumbent, he also receives revenue π and incurs a cost of LR(A)IC via the LR(A)IC-based access price paid to the incumbent. In the latter case, however, the entrant furthermore holds a valuable option to invest in his own infrastructure later on. As explained above, this option is more valuable than the investment itself because it does not need to be exercised in case uncertainty turns out against the firm, thus making an investment unprofitable. So, if uncertainty is substantial, a LR(A)IC-based access price will bias the "make-or-buy"-decision against making/building.

So far, we have focused on construction costs. But renting network infrastructure may be associated with other costs than the direct cost of the LR(A)IC-based access price. For example there are costs associated with negotiating the access agreement and afterwards participating in arbitration. It may also be costly for the entrant to make his own network infrastructure compatible with that of the incumbent. And probably most importantly there may be (strategic) costs associated with relying on the supply of a competitor.

7.2.4 Prof. Hausman's calculations and testimony to the CPUC

Professor Jerry Hausman from MIT has come up with an estimate for the mark-up on (TS)LRIC[171] for telecom network-elements necessary to take account of sunk cost and uncertainty (Hausman 1999). Hausman has earlier presented these "calculations" in a written testimony to the California Public Utility Commission (CPUC)[172]. These calculations are mentioned here because they seem to have been uncritically accepted by many of those criticising (TS)LRIC-based prices. Hausman estimates this mark-up to be 1.35 times (TS)LRIC for links and 0.23 times (TS)LRIC for ports[173].

It is worth mentioning that a substantial amount of Hausman's calculations are based on a simple numerical example of Dixit & Pindyck[174], in which a mark-up of one is calculated ($V^*=2I$). However, this numerical example is used by Dixit & Pindyck to illustrate real-option theory and to give the reader a sense of the importance of considering uncertainty, based on reasonable but not necessarily representative parameters. The example also serves to perform simplified comparative statistics. The chosen parameters have *nothing* to do with the telecom industry. It therefore seems surprising that a MIT professor uncritically applies these parameters to his calculations. His calculations have also been seriously questioned (see e.g. Hubbard and Lehr (1996)). And in its decision of 18 November 1999, the CPUC rejects these calculations, choosing TELRIC, plus 19% to recover fixed and common costs, as the appropriate standard for determining the price of access to unbundled telecom network elements.

7.3 Critique of the option pricing critique/"in defence of LR(A)IC"

There are at least three possibly valid objections against attributing too much (if any) weight to the option critique of LR(A)IC-based prices. First, one can question one or more of the assumptions justifying a real-option approach. Second, one can argue that this bias against the

[171] Hausman already here makes a formal mistake since network elements in the US not are priced according to TSLRIC but instead TELRIC (see footnote 77). However, Hausman's critique applies to TELRIC as well.
[172] It is worth keeping in mind that Hausman worked as a consultant for an incumbent access provider, Pacific Bell, who is benefiting from high access prices. Whether Hausman has been hired because he holds his position or holds his positions because he has been hired will be left for the reader to decide.
[173] The underlying calculations are not well documented. But they are found as a general mark-up for sunk assets of 3.2-3.4, times an estimate for the proportion of sunk costs, which Hausman estimates to be 0.59 for links and 0.10 for ports (Hausman 1999).
[174] Found in Dixit & Pindyck (1994) p. 153.

incumbent is only appropriate to balance the incumbent's first mover advantages. Third, one can argue that LR(A)IC already include the opportunity cost through e.g. relatively short depreciation horizons even though the latter is of course not really a critique.

7.3.1 The assumptions justifying a real-option approach revisited

The first objection is that many networks or network elements do not comply with some of the assumptions justifying a real-option approach. All three assumptions can be questioned:

First of all, one may question how uncertain investments really are, whether it is appropriate to model uncertainty over the investment value with a geometric Brownian motion and whether a different specification of uncertainty would reduce the option value.

Secondly, Hubbard and Lehr (1996) and Economides (1999) question whether investments in telecommunication network infrastructure are really as irreversible as they are often assumed to be. They mention that many parts of the network can be sold for alternative use: e.g. switches can be moved to other locations, real estate can be sold and local loops can be used for other purposes such as ADSL.

Thirdly, and most importantly, it may be questioned whether the firm is able to postpone the investment with the only cost being foregone revenue. This assumption becomes particularly questionable when other firms also hold (or potentially will hold) a similar option to invest. Dixit & Pindyck demonstrate that an option premium *may* remain in an oligopolistic setting, but that it depends on the parameters. In their two-firm model, the option value of waiting is competed down to zero. But the firms will still require a premium on top of the investment cost because "[t]he *firm contemplating being the first to invest recognises that future entry by the other firm will reduce the upper end of the distribution of profit flows. Therefore it requires enough of current premium in compensation. Unlike the perfectly competitive case, though the expected present value of the firm at this point is positive.*" (Dixit & Pindyck p. 309-314).

7.3.2 Strategic incentives in an oligopolistic setting[175]

The first-mover advantage may be substantial in network industries. Brand recognition is important and *customer inertia* seems to be substantial: Even though the services produced in telecom, gas and electricity are very homogeneous products and even though (pecuniary)

[175] This is related to questioning the value of option to wait.

switching costs are low (typically they are zero) customers seem to require a substantial discount before they are willing to switch to a new operator[176]. Also, as noted by Economides (1999), many buyers typically prefer to buy services from an integrated operator - the owner of the network. These effects will tend to reduce a possible bias towards buying/renting instead of making/building.

One could also argue that in order to "level the playing field", access prices should be set lower than the true costs in order to balance the first-mover advantages of the regulated incumbent (in other words, a bias is appropriate). This requires an asymmetric type of regulation where only the incumbent's access prices are based on LR(A)IC.

A third way to defend LR(A)IC is to argue that LR(A)IC-based prices already include a compensation for the option to invest/wait, say through a relatively short depreciation horizon, though this is not really a defence of the principle itself. Section 7.5 below returns to this point.

A final way to question the application of real-option theory concerns the methodology. Real option theory implicitly assumes that firms themselves apply the option approach to their investment decisions instead of the NPV criterion. This may not be the case in practice. This is an argument of irrationality and it will not be pursued further. It is worth keeping in mind, though[177].

7.4 Regulatory uncertainty

Up until now, we have taken regulation as given and assumed that the regulator with certainty would require access to the incumbent's network and set the access price based on LR(A)IC. But maybe the most important uncertainty, faced by the investing firm, is regulation itself. Will the regulator require access to the incumbent's network for competitors? And if so, will this requirement apply to entrants as well? Will access prices be determined by industry negotiation or by regulation? If the access price is regulated, will it be based on LR(A)IC or another pricing principle such as e.g. the ECPR (described in chapter 5)? If the regulator chooses LR(A)IC, which costs will be compensated and how will the capital base be determined? What will be "a

[176] "Pecuniary" is added because if consumers are supposed to be rational there must then be some "perceived" switching costs like effort, fear of lower quality etc. In telecom, the lack of number-portability previously implied a substantial switching cost: you needed to get a new phone number.
[177] It is a point that I have not seen discussed neither by critics nor by proponents:

reasonable return" on the invested capital? Etc. And maybe even: will the firm be compensated for the extra opportunity cost associated with "killing" its option to invest.

In the above "model", this would be uncertainty over the price, P', instead of over demand. Regulatory uncertainty is, of course, unlikely to follow a Brownian motion but then again it is difficult to find another specification of uncertainty that seems much more obvious. And as mentioned earlier an option premium will apply for most other specification of uncertainty as well. The important thing to note is that future revenue and therefore the value of the investment is highly dependent on the regulatory environment and that regulatory uncertainty increases the value of waiting for more information to arrive from the regulator, thereby discouraging investments. Thus, to ensure that efficient investments are undertaken, it may be just as important that the regulator specifies a transparent and predictable regulatory regime for regulating access and access prices, as it is that these access prices are appropriately determined.

7.5 Regulatory implications of real-option theory

As mentioned above, one of the most important lessons for regulators and legislators probably is the importance of minimising regulatory uncertainty in order to encourage efficient investments. They should quickly determine whether to require access for competitors and, if so, provide guidelines on how access will be regulated and in particular decide on the principles for determining the access price. The value of regulatory certainty seems to be an argument in itself for requiring access to networks. The point is that it is very difficult for regulators and legislators to credibly commit themselves not to require such access sometime in the future. As long as access is not required, regulatory uncertainty persists. For example the British NRA, Oftel, firstly favoured not to require access to unbundled local loops in order to spur infrastructure competition. In November 1999, Oftel changed its mind and proposed requiring access to unbundled local loops - but not until July 2001[178]. Only three months later, Oftel now (April 2000) seems to be favouring unbundling the local loops before the end of this year, following an expected recommendation from the European Commission in April 2000[179] [180].

[178] Oftel (1999) - Access to Bandwidth: Delivering Competition for the Information Age. November 1999 http://www.oftel.gov.uk/competition/a2b1199.htm
[179] See Commission (2000): Working Document of DG13 (INFSO) A1 on "Unbundled access to the local loop", 9 February 2000. http://bscw2.ispo.cec.be/infosoc/telecompolicy/en/ullwd10b.doc

The other important lesson is that the regulator, when determining the access price, should evaluate to which extent the investment is reversible, how important uncertainties over revenue and investment costs are and whether the operator has managerial flexibility to postpone the investment decisions. If (and only if) the answers to *all* of these three questions are in the affirmative, the regulator should allow for an appropriate compensation for the lost option premium associated with "killing" the option to invest. This should be done in order to provide the incumbent with efficient investment incentives as well as to provide entrants with an unbiased buy-versus-make signal. In order to achieve dynamic efficiency, the regulator will consequently have to accept that the incumbent/investing firm, from a static point of view, is being overcompensated for its incurred costs. A general rule of thumb for evaluating this extra opportunity cost can not be established, however, because the degree of uncertainty, irreversibility and managerial flexibility may vary substantially from network industry to network industry and from one network element to another.

Estimating such option premiums correctly is extremely difficult, if not almost impossible, for the regulator. Furthermore, the addition of an option premium is unlikely to gain political acceptance. A practical way to incorporate a premium to the firm when using LR(A)IC is to base the LR(A)IC calculation on relatively short depreciation horizons, compared to those that would be set from an engineering or traditional economic point of view. Such a solution is probably more likely to gain political acceptance. A shorter depreciation horizon will increase prices in the short run but also lower them in the long term. Hereby the regulated firm will be able to recover a larger part of its cost in the near and less uncertain future, which seems to be acceptable from a political point of view. A shorter depreciation horizon provides the regulated firm with an extra premium because revenue in the near future is worth more than revenue in the distant future. Alternatively, a relatively high return on capital - higher than that proposed according to the CAPM - could be employed. Again this is probably unlikely to gain political support

The presented analysis of price regulation and real-option theory applies to all kinds of regulated firms with managerial flexibility, which face irreversible investments under uncertainty. The results are not limited to the access-pricing problem.

[180]Already in its November document it was noted that the timetable might be revised if Oftel found that an earlier implementation date could be practically achieved (point 2.34)

Chapter 8

'Case': Local loop unbundling (LLU) in the EU

This chapter describes the need for requiring access to unbundled local loops (ULLs) in telecom and discusses how the price of these ULLs should be determined. The chapter ends by discussing two important non-price issues and the implications of applying real-option theory to the analysis.

This case has been chosen because it first of all illustrates many of the regulatory issues discussed in this thesis, in particular the issue of uncertainty. Secondly, because the pricing of ULLs will be a main regulatory issue in the EU in the next couple of years. And finally, because the issue of LLU is much less covered in the literature than the issue of interconnection is.

8.1 The case for requiring access to local loops

8.1.1 Cost structure of the fixed access network

As described in chapter 2, section 2.1, telecom networks are characterised by large economies of density, network externalities and monopoly over access. Therefore, incumbents have been required to interconnect with entrants, allowing these to offer competing services such as international telephony over the incumbent's network. Due to the technological development, in particular digitalisation and deployment of fibre technologies, the economies of scale in the core (national) network have been reduced dramatically. Consequently, the core network can no longer be considered to be a natural monopoly and competing network operators are currently rolling out network infrastructure across Member States, allowing them to compete on long-distance telephony as well.

In the local access network, however, the economies of density remain substantial. Here the main costs arise from laying down the copper (or fibre) wires, and those costs have not fallen, maybe they have even increased. As a result, it has not (yet) been economically viable for entrants to build their own access networks. Local access provision can therefore still be characterised as a natural monopoly where competition does not yet exist - at least for private and small businesses[181]. To give an idea of this natural monopoly, table 8.1 below compares the book values of Tele Denmark's assets with the estimated costs of establishing a new network calculated according to a green field model (described below).

	TDK's cost distribution	Book value of assets	Green field Cost distribution	Green field (DKK bn)
Access network	20%	2.6	54%	11.2
Transport network	25%	3.3	15%	3.0
Central infrastructure	30%	4.0	16%	3.2
Buildings & administration	15%	2.0	9%	1.9
Other	10%	1.3	6%	1.3
Total	100%	13.2	100%	20.6

Source: Ministry of Research and Information Technology (1999), referring to Andersen Management International. Based on information from Tele Danmark 1996

Table 8.1 - Estimated book value of Tele Danmark's network parts
versus the green field model of a new network

As the figures illustrate, all parts of the network, except the local access network have become cheaper to construct today despite the depreciation of book values. Construction of a competing fixed access network, however, would be 4-5 times more expensive than the book value of the assets used in the existing access network: First of all, because the existing access network has been strongly depreciated. Secondly, because it, as opposed to the core network, has become more costly to build. The current regulated prices, which competitors would have to compete with, are based on the book value of Tele Danmark's assets. Construction of an alternative fixed access network is therefore not economically feasible. Hence, the access network constitutes a natural monopoly[182].

Due to the introduction of *carrier pre-selection,* where consumers can choose another operator for the entire subscription or for certain types of calls; and *number-portability,* where the consumer can move his phone number along to a competing operator, this natural monopoly is not a real impediment to competition over basic voice-telephony as long as the interconnection

[181] From the consumer side it may appear as if competition has arrived because consumers in most Member States are now able to choose between different operators for the entire subscription. However, these operators are typically just reselling the access service of the incumbent. They have to pay a per-minute price to the incumbent, and it is this price for which there is no competition.
[182] Strictly speaking, due to convergence one have to investigate substituting access technologies before one can term the fixed access network a natural monopoly. This will be done below.

charges (for call origination and call termination) are properly regulated. Cost-effective competitors should be able to offer basic voice telephony products comparable to that of the incumbent at competitive prices.

However, for more advanced products, like broadband (Internet) access, such as ADSL[183], and products integrating mobile and fixed telephone, such as Duet[184], entrants will be highly dependent on the incumbent unless they are provided with physical access to the local loops. It may be possible to offer competing products, reselling the access product of the incumbent, say through indirect "bit-stream" access, but then a substantial amount of the product will continue to be produced by the incumbent. Consequently, the competitive pressure on the incumbent to minimise cost and to innovate is substantially weakened compared to the case of physical access to the loops, where entrants produce most of the services themselves. The two kinds of access are illustrated below in figure 8.1. Bit-stream access is similar to the kind of voice-telephony interconnection we see today. Here the point of interconnection is placed on the network side of the incumbent's switch and the entrant typically pays a per-minute charge. With local loop rental, the entrant interconnects on the customer's side of the incumbent's local switch and typically pays a fixed monthly rental charge[185].

[183] Asymmetrical Digital Subscriber Line. The International Telecommunication Union (ITU) has worked out technical specifications for ADSL full rate with speeds up to 8 Mb/s downstream and 1 Mb/s upstream. ADSL can achieve its highest speeds at a distance of 4km or less. The connection allows the provision of voice phone service on the basic frequency band of the same line. In addition ITU has worked out a variant ADSL solution known as G.Lite, that is very easy to deploy in the customer premises because it is ‘splitter-less’ (it needs a very simple serial filter that separates voice and data and does not call for any rewiring at the customer premises). Speeds are up to 1.5 Mb/s downstream to the user and 385 Kb/s upstream. Commission (2000): Working Document on "Unbundled access to the local loop", http://bscw2.ispo.cec.be/infosoc/telecompolicy/en/ullwd10b.doc. See also works of the Universal ADSL Working Group - Public forum http://www.adsl.com/dsl_forum.html

[184] Briefly described in chapter 5 in footnote 102.

[185] For more on the technical aspects of LLU and bit-stream access see OVUM (1999).

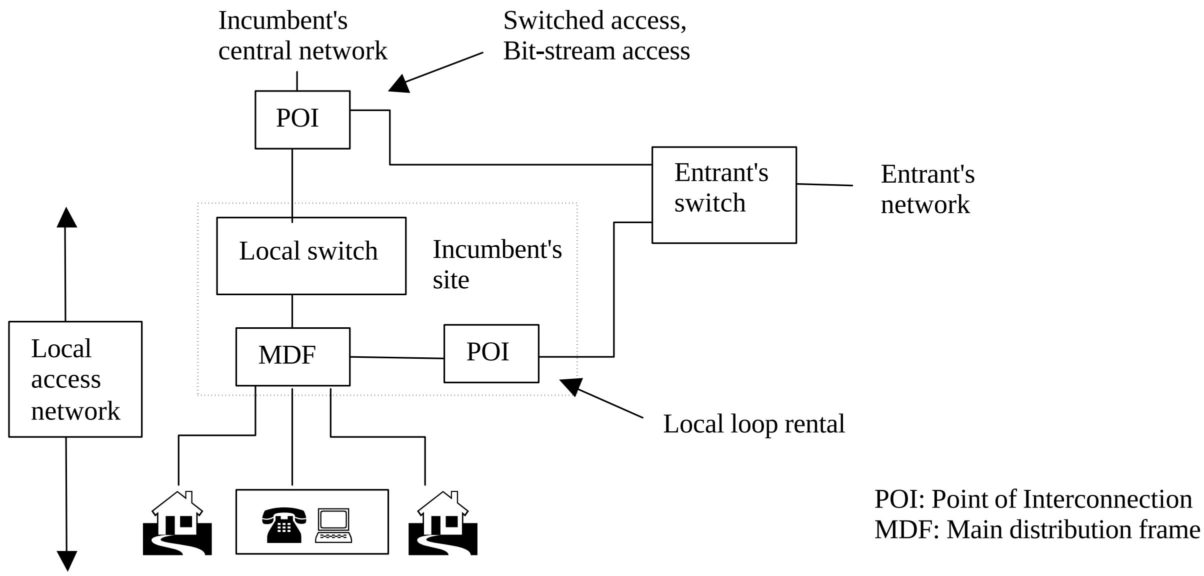

Figure 8.1 - Different forms of rented access to customers

Adapted from OVUM (1998)

In addition to reducing the entrant's reliance on the incumbent, physical access allows the entrant to deploy different technologies in the local loop as well as to introduce innovative pricing schemes, such as e.g. flat-rate Internet access. From a regulatory point of view LLU has the benefit of reducing the natural monopoly to the loop itself. Regulating local-loop access is a complicated regulatory task, but when entrants have first established a sufficient amount of interconnection points, it should in turn be possible to lift regulation on all retail services and reduce wholesale regulation to the local loop and call termination[186]. Then regulators would e.g. not have to worry about regulating the price, technology or rollout of ADSL[187].

The disadvantages of physical access compared to bit-stream access are primarily on the technical side: Network modernisation becomes more difficult for the incumbent, and there may be problems with interference between the lines if different technologies are deployed. Another problem, some argue, is that local loop rental undermines the incentives to build alternative

[186] As described in chapter 2 the need for regulating (or at least monitoring) call-termination charges remains because operators hold a monopoly over terminating calls to their subscribers.

[187] Except a requirement that the deployed technologies do not interfere with each other.

networks. The counter argument is that local loop rental on the contrary reduces the costs and risk of entry by allowing entrants to build up a critical mass of customers before constructing there own access network. In the long run it may therefore lead to *more* investments in competing access networks - not less.

8.1.2 Alternative access networks

Before concluding that physical access is required based on the above arguments, it is necessary to investigate whether substituting technologies exist. The main substitutes for the fixed telephony network are: mobile telephony, Fixed Wireless Access (FWA) and Cable-TV.

Mobile telephony is already today a substitute for basic voice telephony. It offers greater functionality but is still much more expensive and the quality is lower[188]. Prices are falling and quality is improving but mobile telephony still offers much smaller capacity for data transmission than the fixed network and can therefore not be considered a real substitute for the fixed access network[189]. A 3rd generation mobile system, UMTS, with broadband capacity almost comparable to that of ADSL, is being developed but network rollout will not begin until 2002 in the EU.

Fixed Wireless Access (FWA) is based on digital radio technology in the local loop instead of fixed lines. This reduces entry costs and like mobile telephony provides entrants with much more flexibility with regard to building out their networks. Licenses will be offered in 2000 in most EU Member States and capacity will be comparable to that of ADSL. However, FWA is expected to be somewhat expensive, making it first of all a viable substitute for large businesses. It may become an attractive substitute to the fixed local loop in the future, though.

Cable TV (CATV) networks are already in place in many Member States and cable modems exist, offering high speed Internet access to residential customers. Such a set-up, however, typically requires a fixed phone connection as well for up-stream traffic because most cable networks are typically designed as one way networks[190]. But these networks have the potential of being upgraded to two-way networks[191]. From a regulatory point of view, however, CATV can only be considered a substitute for local access, if CATV networks are owned by operators, who compete with the incumbent telephone operator. This is the case in only half of

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[188] Due to call dropouts, a lower quality of transmission and poor in-building coverage.
[189] Data capability is currently limited to 9.6 Kb/s (OVUM 1998)
[190] This is e.g. true for Danish Tele Danmark's CATV network.
[191] Swedish Telia is e.g. offering two-way broadband access via its cable network.

the EU Member States. In countries like Denmark, Finland, France, Germany, Ireland, Portugal and Sweden the incumbent telephone operators also own the CATV network. The Commission has therefore issued a Directive[192] "to ensure that telecommunications networks and cable TV networks owned by a single operator are separate legal entities"[193]. Such an action will make it easier to monitor that the joint operator is not abusing his dominant position in either of the markets to obtain a competitive advantage in the other, and should reduce the incentive to do so. Absent separate ownership, however, the incentive to act as one company remains because the surplus goes into the same pockets[194].

Other (potential) substitutes may be broadband access via the electricity distribution network, satellite or microwave links. At present these access technologies, however, do not offer a sufficiently close substitute for the fixed local loop.

We are now ready to conclude that LLU is necessary to introduce true competition over local telephony access and broadband access in particular. At present, construction of a competing fixed network is not economically viable and existing alternatives can not be considered good enough substitutes, because they do not offer similar capacity, because they are not as cost effective or because the competing access network is owned by the same operator as the fixed telecom network. In the future, when alternative access networks develop and infrastructure competition over broadband access is established, a requirement for LLU may be withdrawn.

In the above, a distinction has been made between two solutions: LLU and bit-stream access. The two solutions are not mutually exclusive, however. LLU is the closest we will get to complete infrastructure competition when the local loop remains a natural monopoly. But even

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[192] Commission (1999): Directive 1999/64/EC of 23 June 1999 amending Directive 90/388/EEC in order to ensure that telecommunications networks and cable TV networks owned by a single operator are separate legal entities. http://europa.eu.int/eur-lex/en/lif/dat/1999/en_399L0064.html

[193] It has been left for the Member States, however, to decide whether the Directive applies. The Directive stipulates that *"Each Member State shall ensure that no telecommunications organisation operates its cable TV network using the same legal entity as it uses for its public telecommunications network, when such organisation: (a) is controlled by that Member State or benefits from special rights; and (b) is dominant in a substantial part of the common market in the provision of public telecommunications networks and public voice telephony services; and (c) operates a cable TV network established under special or exclusive right in the same geographic area."*.

Denmark has transposed this requirement into §92 of a proposal of March 2000 for a new telecom legislation. It has not yet been finally decided whether the three cumulative requirements (a-c) all apply to the Danish incumbent, Tele Danmark, but most likely they do. Tele Denmark is therefore likely to be forced to separate its cable company into a separate legal entity. This is supported by the fact that the Commission according to the comments on §92 considers Tele Denmark to benefit from special rights.

[194] See also the discussion of monopoly leveraging in chapter 5, subsection 5.3.7.

when local loops are unbundled it may be too costly for entrants to rollout a network, establishing points of interconnection at all the incumbent's local switches, when the entrant has only a few subscribers connected to each switch. In order to allow entry into broadband provision on a smaller scale, it therefore seems appropriate to combine the two types of access provision, allowing entrants to reach a critical mass of customers before building out their networks. Then they can establish points of interconnections when it is economically feasible and continue to use bit- stream access elsewhere. However, the incumbent should be able to recover all his costs including a reasonable profit on his investments, necessary to provide entrants with bit-stream access for a limited period[195].

8.2 EU legal framework for requiring access to local loops

Based on the brief analysis of the EU essential facility doctrine in chapter 3, it was concluded that its concept of an essential facility might be too weak to sustain a requirement for LLU based on EU competition law alone[196]. In the *Bronner* Case, the European Court of Justice ruled that a (newspaper) distribution network could only be considered an essential facility, to which competitors should be granted access, if duplication of the facility were not economically viable, even for an operator of comparable size. In telecom, the largest problem for entrants is reaching the critical mass sufficient to make an investment in infrastructure economically viable. Based on calculations similar to those presented in table 8.1, indicating the high cost of duplicating the entrants fixed network, it may be argued that investment in infrastructure is not viable even for an entrant with a size similar to that of the incumbent. However, one should also remember that LLU is very intrusive to the incumbent's way of doing business, compared to say sharing a network for newspaper distribution. Also incumbents already today offer entrants access to end

[195] In technical terms the incumbent should be allowed to add a larger mark-up to costs - or use a shorter depreciation horizon for calculating costs - for bit stream access than is used for ULL. Entrants will then also have an incentive to rollout their own networks. If this is not the case entrants might require bit stream access and then shortly after, not taking into account the costs associated with bit-stream access. This might bias the entrant's investment incentives and leave the incumbent with some stranded costs, for which he has not been responsible. To avoid the latter, the incumbent should also be given the possibility to refuse a request for access provision if he, for objective reasons, can argue that such access impose unreasonable costs upon him.

[196] An alternative approach would be to argue that ULL rental ought to be considered a separate product from other telecom services, and that refusal of providing access to ULL therefore corresponds to *tying* two separate products. Tying constitutes abuse of a dominant position according to Article 82(d) EC. It is unclear whether such a case could turn out in favour of LLU. It seems like turning economic realities upside-down.

users via switched access. It is therefore not likely that LLU could be required based on competition law alone.

From an economic point of view, however, such an "equal-size benchmark" is inappropriate due to the massive economies of density and problem of reaching a critical mass of customers. On the contrary, it should appear from the above argumentation, that LLU is indeed required, in particular to introduce competition over broadband access to the Internet. Hence, there is a need for sector-specific regulation. Such regulation has already been implemented in Austria, Denmark, Germany, Netherlands and Finland as well as in Canada and the US. A status on LLU in these countries is presented in Appendix C.

No EU legislation on LLU has yet been passes. But a Commission Working Document on LLU has been published recently[197] and a Commission recommendation of LLU is expected in April 2000. The recommendation will also include a number of guidelines regarding LLU. Such guidelines are strongly needed to avoid increased fragmentation between Member States.

The EU-competition-law principle of non-discrimination obviously applies to ULL as well: If the incumbent chooses to offer access to ULL to one operator, it has to make a similar offer available to all other operators[198].

8.3 Should the LLU-requirement be limited in time?

As mentioned in chapter 5, proponents of infrastructure competition are opposed to LLU, arguing that it removes the incentive to invest in competing access networks, thus obstructing the introduction of full "head-to-head" competition. Even the critics, however, have to accept that the development of competing access networks has been slow, also in countries without a requirement for LLU. As a compromise some regulators have therefore adopted an approach of requiring LLU only for a given period only in order to "kick start" competition without removing the incentive for investment in alternative infrastructure. In Canada e.g. LLU was introduced in

[197] Commission (2000): Working Document of DG13 (INFSO) A1 on "Unbundled access to the local loop", 9 February 2000. Section 2.1.3.1 http://bscw2.ispo.cec.be/infosoc/telecompolicy/en/ullwd10b.doc

[198] On 27 July 1999 the Commission actually decided to open a sector inquiry under the EU competition rules relating to inter alia the tariffs for the provision of access to and use of the residential local loop. By means of this investigation, the Commission wishes to determine whether the practices and prices observed constitute infringements of EC competition rules, in particular of Articles 81 and 82 of the EC Treaty. Commission (1999) 5th implementation report.

May 1997, though only for a 5-year period in (low-cost) urban areas. In (high-cost) rural areas the local loop was expected to remain an essential facility, why no time limit was attached. It was argued that the 5 years would allow entrants to build up a critical mass of customers in order to make investment in their own access networks economically feasible. In March 1999 a similar kind of LLU was introduced in the Netherlands, requiring LLU for a period of 5 years for all loops[199]. While the price in Canada was calculated based on current/replacement costs, the price in the Netherlands was at the outset calculated from historic costs. But during the 5 years, the price is gradually adjusted (upwards) towards a price, calculated based on current costs[200]. Such a price should initially allow entrants to build up a customer base, while at the same time gradually increase the incentive to invest in alternative infrastructure. By the end of the 5-year period, the price should reflect replacement costs - a price that is consistent with a competitive market and which does not bias the 'make/buy' decision of entrants. OPTA (the Dutch NRA) considers 5 years to be the minimum period for earning a return on the initial investment. OPTA also refers to the Canadian experience and points to the fact that third generation mobile, UMTS, will be introduced before the end of the 5-year period, offering broad access comparable to the fixed local loop.

At first glance such a time limit may seem appealing because it is designed to introduce competition while at the same time guide competition towards full infrastructure competition. A problem with this approach, however, is that it assumes that investment in alternative infrastructure will be viable before the end of the period. As indicated by the figures in table 8.1 investment in an alternative fixed network seems unlikely due to the very high investment costs. At best, the investment in an alternative fixed access-network seems to imply unnecessary duplication of costs. Only where installation of new access technology such as fibre and FWA is possible does investment seem attractive from an economically point of view. Fibre, however, is only economically viable for large customers and the economic attractiveness of FWA remains to be seen. The local loop may therefore remain an essential facility for smaller customers even in urban areas also 5 years from now. If entrants share this view, a time limit increases uncertainty because they do not know to which extent their investment will be lost. The time limit also reduces the possibility of recovering the investment cost associated with establishing the points

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[199] The density in the Netherlands is naturally much higher than in Canada.
[200] According to the formula $P_t = P_t^H + 5/t\,(P_t^C - P_t^H)$, where P^H is the price based on historic costs, and P^C is the price based on current costs. These prices are recalculated annually.

of interconnection at the incumbent's main distribution frames. Thus, time limits definitely make local loop rental less attractive compared to building an alternative access network. However, there is also a risk that entry will never take place or at least take place on a smaller scale. Regulators should therefore avoid limiting the access to unbundled local loops to a given period.

On the other hand, there is no doubt that alternative access networks eventually will be constructed using alternative technologies such as cable, FWA and UMTS. Regulators should therefore ex ante consider the possibility of terminating the LLU-requirement when sufficiently substituting access networks exist. However, such a termination should not be fixed before these access networks are in place. In order to provide sufficient certainty for entrants, with this in mind, it is appropriate that regulators, when they require ULL-access, also specify a minimum notification period, say two years, before the LLU-requirement can be terminated[201].

It is still too early to conclude how these time limits affect investment incentives in practice. In Canada, however, where there is only 2 years left of the LLU-requirement in urban areas, it is uncertain whether the time limit will be extended or not. But it is certain that entrants will apply for an extension of the date, arguing that the 5 years have *not* represented enough time for them to achieve a levelled playing field. To the extent that ULLs are indeed priced at (true) LRIC in Canada this supports the above criticism of time limits. A final argument against limiting the period of the LLU-requirement is that, at least in theory, it may give the incumbent an incentive to delay investments in the network until the end of the period.

8.4 Regulating the rental price of ULLs

8.4.1 LRIC+

Referring to the discussion in chapter 5, the appropriate pricing principle for determining the price of access to ULLs is (forward-looking) Long Run Incremental Cost (LRIC) plus a mark-up to cover joint and common costs as well as a reasonable return on the invested capital (LRIC+). So far, the thesis has consistently referred to LR(A)IC, because "LRAIC" has become an established term for pricing interconnection. For interconnection all the relevant incremental costs associated with delivering the interconnection service are added up and *averaged* out over

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[201] The British regulator, Oftel has e.g. proposed to set out a 4-year period after which the ULL requirement will be reviewed every second year. Oftel (1999) - Access to Bandwidth: Delivering Competition for the Information Age

the total amount of traffic/call minutes generated by the operators seeking interconnection as well as the operator providing interconnection. For unbundled local loops, however, operators are not just getting access to part of the capacity. They obtain *exclusive* access to the entire capacity of the local loop - and only the local loop. The incumbent's cost of providing such exclusive access is independent of the amount of traffic. Hence, the price should be based on the entire LRIC associated with providing the particular network element, here the ULL, and should in order to achieve allocative efficiency be collected as a fixed, say monthly, rental charge independent of traffic/call minutes.

An important thing to note about LRIC, when pricing access to ULLs, is that the approach, unlike for interconnect charges, implies prices, which are higher rather than lower than the current prices based on historic fully distributed costs. The reason is that the current-cost-asset-value of the access network as illustrated in table 8.1 and mentioned by OVUM (1998) usually is higher than historic-cost values while the opposite is the case for the core network. One may sometime wonder whether politicians are fully aware of this fact when they argue so strongly in favour of using LR(A)IC for determining the price of ULLs as well.

The regulator also has to determine who should pay for transferring the loop from one network to another. Because it is the consumer and thereby indirectly the entrant, who is requesting the transfer, it should also be the consumer, who faces these costs via the entrant. Whether the entrant chooses to cover the costs via a one-off charge, via a monthly rental charge or via the call charges should then be left to the entrant to decide. The important thing from an allocative point of view is that the entrant is paying for these costs via a one-off charge and not via the rental fee. Should the customer decide to switch back to the incumbent later on, it should be the incumbent who pays the cost associated with switching back the local loop.

When LLU has been required, the regulator will also have to provide guidelines with regard the pricing of *collocation*, i.e. the sharing of buildings between the incumbent and the entrants, who needs to install their equipment on the incumbent's premise. It would be outside the scope of this thesis to go into the problem of collocation[202].

November 1999 http://www.oftel.gov.uk/competition/a2b1199.htm

[202] Fore more on collocation and the regulation of it see study for the Commission by Eutelis Consult/Horrocks Technology/Tera Consultants of January 1999: "Recommended Practices for Collocation and other Facilities Sharing for Telecommunications Infrastructure". http://www.ispo.cec.be/infosoc/telecompolicy/en/Study-en.htm. One observation on collocation will be made though: There is an additional risk associated with being the first to establish a premise/collocation facility compared to other operators, who can later gain access to this facility if demand turns

8.4.2 Geographically averaged versus geographically de-averaged rental prices

The advantages and disadvantages of averaged prices were briefly discussed in chapter 2 subsection 2.2.1**.** The question is whether the regulator should require a uniform rental price of the loops across the country or whether prices should reflect geographic cost differences. From an equity point of view, it may seem appealing to impose geographically averaged prices to ensure affordability of voice telephony and high speed Internet access in rural (high-cost) areas. From an efficiency point of view, however, the problem with averaged rental prices is that they bear a risk of distorting investment decisions, causing inefficient bypass in low cost areas and under-investment in high cost areas. In low cost (urban) areas the rental price will be set above LRIC+. Entrants may therefore choose to invest in their own access network even though, from society's point of view, it would have been less costly to rent the local loops from the incumbent. In high cost (rural) areas, on the other hand, the rental price will be set below LRIC+. Entrants will therefore typically choose to rely on local loop rental, ignoring the true costs to society. This becomes a real problem if entrants can require incumbents to construct new lines and then subsequently rent them. In addition to biasing the investment decision of entrants, averaged prices may also remove the incentive for incumbents to rollout or to upgrade their network in high-cost areas where they are not able to cover their costs.

De-averaged prices, on the other hand, are likely to cause problems in a world where most other prices including interconnection prices and retail rental prices are geographically averaged. Entrants will inevitably engage in arbitrage pricing, preying on the artificially high competitive margins in low cost areas created by the relatively high retail prices in these areas compared to the wholesale price of ULLs. As long as entrants are more efficient than the incumbent such arbitrage is welfare enhancing. The problem is that the artificially high margins allow inefficient entry as well. Forcing de-averaged prices on the incumbent's LLU is therefore likely to undermine geographically average retail prices in the long run. One might suggest setting up a Universal Service Fund for subsidising high cost (rural) loops. The problem with this approach,

out favourably. It therefore seems appropriate to compensate first-comers through allowing a slight over compensation of their costs, should entrants later require collocation. Technically this could be done by lowering the first-comer's contribution to the costs of collocation below his market share. Such a scheme is naturally likely to meet strong resistance from entrants but may, following the discussion of real-option theory and regulation, be necessary to achieve dynamic (investment) efficiency.

however, is that one may end up supporting a lot of profitable (high-volume) rural customers as well. The Universal Service Obligation will no longer be calculated on a net-cost basis[203], and the burden, associated with it, will consequently be increased.

As should be clear from the above discussion, it is not possible to give a definitive answer to the question about whether or not to require averaged prices. From an efficiency point of view, the price of ULLs as well as retail prices ought to be de-averaged, though this will not be compatible with equity considerations. As a result it seems appropriate to begin with geographically averaged prices but with the possibility of allowing the incumbent to de-average prices if he (on objective terms) can justify the cost differences. If incumbents are unable to cover their costs plus a reasonable profit due to geographically averaged price the regulator could also consider adding an additional mark-up to the LRIC+ price as an alternative to de-averaging the price[204]. It also seems appropriate to introduce downward flexibility from LRIC+ to enable incumbents to compete with (inefficient) by-pass.

Having considered some of the arguments above, the Commission finds it "inappropriate to issue at a European level a specific recommendation on geographic averaging or de-averaging of the price of unbundled local loops"[205]. In the US, the FCC has decided that rates for interconnection and unbundled elements must be geographically de-averaged, where there are significant cost variations[206].

8.4.3 Margin squeezes

In its recent Working Document on LLU[207] the Commission points out the problem of margin squeezes, which arises when retail prices are not balanced - when they are cross-subsidised as described in chapter 2. The Commission is referring to the situation where retail rental prices are relatively low compared to the wholesale rental price of ULLs, leaving little room for entrants. It

[203] See chapter 4, subsection 4.2.4
[204] Such an approach somewhat resembles financing the USO via an access-deficit charge - an approach criticised in chapter 4, subsection 4.2.4. 1) Because the contribution can be avoided by bypassing the incumbents network. 2) Because it is collected on a *per-minute* base, thus distorting usage. Here such an additional charge is much less distorting because it is charged on a *per-line* basis and because it applies to operators using the local loop one way or the other. However, it can still be avoided by bypassing the local loop, and thus biases the make-buy decision against buying (renting the local loop).
[205] Commission (2000): Working Document of DG13 (INFSO) A1 on "Unbundled access to the local loop", 9 February 2000. Section 2.1.3.1 http://bscw2.ispo.cec.be/infosoc/telecompolicy/en/ullwd10b.doc
[206] FCC (1998) Local competition. Section VII. Pricing of interconnection and unbundled elements, Sub-section B3(c), 4 December 1998, http://www.fcc.gov/ccb/local_competition/sec7.html

is presented as if the incumbent had an incentive to engage in such a margin squeeze to deter entry. This may at first seem very intuitive but is harder to justify based on economic theory.

If local loops are indeed unbundled and made available to entrants at cost-based (LRIC+) prices, entrants will target customers who generate a *total* revenue higher than total costs[208]. If entrants can offer a more attractive package (rental price *and* traffic price) than the incumbent, they should be able to attract customers, even if the margin for access alone is small. Thus, the incumbent will not be able to finance its cross-subsidy scheme via high call prices, as seems to be the premise of the Commission's argument[209].

The incumbent may engage in *predatory pricing* like any other firm by charging prices (rental *as well as* call charges), which are lower than costs[210]. However, predatory pricing has been discussed more in theory than it has been observed in practice. A firm, which engages in predatory pricing, loses money in the short term. It only has an incentive to do so if it can eliminate future competition and later earn a monopoly rent, which exceeds the short-term loss associated with predatory pricing. Like in most industries, this seems unlikely in telecom[211].

The incumbent therefore has no incentive to introduce such a margin squeeze when first ULLs are available at cost-based prices (the situation is naturally different absent LLU). On the contrary, the economic value of lines varies considerably with the intensity of telephone usage under the current tariff structure in most Member States. Customers, whose loops, are transferred to entrants for the purpose of offering high bandwidth (Internet) access, may at the same time transfer their telephone services. And as pointed out by the Commission in its Working Document, the customers switching will in many cases be customers who generate above-average

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[207] See footnote 205

[208] If entrants offer services other than basic voice telephony such as high speed Internet access or video-on-demand the revenue from these services contributes to total revenue just like call minutes and line rental.

[209] If entrants are much more cost effective than the incumbent, the incumbent might at least in theory even choose to unbundle the local loops himself if he believes he can generate more revenue from outsourcing the competitive part of the service than he can by producing it himself. Naturally, such an incentive would only arise if the incumbent was allowed to charge a price for ULL-rental high enough to earn a profit similar to the one he earns without LLU - thus a price similar to the ECPR price discussed in chapter 5.

[210] Predatory pricing constitutes abuse of a dominant position according to article 82(a) (ex 86a), which prohibits directly or indirectly imposing unfair purchase or selling prices or other unfair trading conditions.

[211] A theoretical example of predatory pricing would be an incumbent charging unfairly low prices for access in order to eliminate competition from (emerging) infrastructure providers. However, one may first question whether it would at all be possible to deter entry since entrants typically are backed by substantial amounts of capital. Second, one may question whether the incumbent can expect a regulator to later accept a substantial price *increase* when the incumbent has previously argued the low price to be cost based. Finally, future technological development makes such a strategy - exchanging short-term revenue for long-term revenue - highly risky.

telephone revenues, thus reducing the average level of profitability of telephone customers remaining with the incumbent.

The incumbent therefore actually has a strong incentive to rebalance tariffs in order to avoid cream-skimming (see chapter 2). Practice also indicates that incumbents typically argue in favour of tariff rebalancing, while entrants argue that it leaves them no room for competition because of the lower margins ("price squeeze") per call minute. Likewise, incumbents would benefit from geographically de-averaged prices[212].

As concluded in chapter 2, regulators should allow the incumbent to rebalance tariffs in order to achieve allocative efficiency while at the same time require the introduction of some kind of low-user schemes to minimise the price increase for low-users.

The incumbent does have an incentive to squeeze the margin, though not by lowering the rental price but instead by increasing the price of the monopolised segment, the local loop, in order to leverage his monopoly power over loop provision to the retail market[213]. This is why it is important that ULLs are indeed priced at LRIC+.

8.4.4 Gradual move from historic costs to current costs

As argued above, the incumbent has no immediate incentive to lower the rental price below (forward looking) LRIC+. However, a problem of insufficient competitive margins may still arise, simply because the retail rental price today is already set below LRIC+. In most Member States the retail rental price is currently regulated according to some kind of distribution of historic costs, which in the access network are substantially lower than costs measured according to a current/replacement costs standard - first of all due to depreciation.

(Forward looking) LRIC+ prices for unbundled local loops may therefore not leave entrants with any margin on which to compete - at least not for low-usage consumers[214]. This will surely be a hard nut to crack for regulators. On the one hand, a LRIC+ price is desired in the long run, because it is consistent with a competitive market and because it sends the right investment

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[212] At least if the costs of administrating such a de-averaged cost scheme were not too high.

[213] A price squeeze can be demonstrated by "*showing that the dominant company's own downstream operation [service provision] could not trade profitably on the basis of the upstream price charged to its competitors by the upstream operating arm of the dominant company*". Commission (1998): "Notice on the Application of the Competition Rules to Access Agreements in the Telecommunications Sector", 90/388/EEC, 31 March 1998. http://www.ispo.cec.be/infosoc/telecompolicy/en/ojc265-98en.html. The dominant operator could e.g. allocate costs to his access operations, which should properly be allocated to the downstream operations, or he could use otherwise improperly determined transfer prices within the organisation.

signals to the incumbents as well as to the entrants. On the other hand, the current retail-tariff structure is desired because it ensures access at reasonable costs and favours low-usage consumers. Also one should not forget that the retail price of access and basic telephony has always been subject to regulation in order to allow incumbents to cover their (historic) costs. Some would therefore argue that consumers have already paid past depreciation. One has to be very careful with such an argument, though, because today's incumbents have typically bought the former monopoly from the state including the local access network. The argument should therefore be sustained by claiming that the price at the time of privatisation was determined under the assumption that prices would continue to be regulated. If one accepts these two arguments, allowing the incumbent to charge LRIC+ prices for ULLs would provide him with a windfall gain amounting to accounting depreciation minus actual deterioration/economic depreciation.

To reconcile the desire to achieve LRIC+ prices, compatible with competition and long run efficiency, with the desire to ensure competitive margins to spur competition, a gradual move from a historic cost principle to a current cost principle seems an obvious idea. Such an approach would allow entrants to compete with the incumbent renting his ULLs today, but would at the same time gradually increase their incentives to invest in alternative infrastructure.

As described above, such an approach has been taken in the Netherlands. Here the price is adjusted over a 5-year period, after which it will be left to industry agreements. The latter, seems highly inappropriate because of the risk that the local loop will remain an essential facility beyond the 5-year period. It therefore seems more appropriate to continue regulating the price according to LRIC+ after the 5-year period. Such an approach - a 5-year transition period with prices thereafter regulated according to LRIC+ - is likely to be applied in Denmark for ULLs[215].

8.5 Important non-price issues

Regulators have to provide guidelines regarding quality, spectral management[216], installation time, repair time, service, collocation etc. to prevent the incumbent from engaging in anti-competitive behaviour[217]. Two additional issues are important with regard to LLU:

[214] As pointed out above, entry may still be viable if entrants can regain this loss on call minutes, Internet access etc.
[215] Comments on §55(5) of Bill L248 of 30 March 2000 on law about competition and consumer issues for telecommunications, http://www.fsk.dk/fsk/div/love/l248.doc
[216] Ensuring that interference is not a problem.

8.5.1 Information about incumbent's network

Regulators will have to require the incumbent to provide other operators with information about the location of his local switches (or rather main distribution frames) and the precise areas they serve. This is necessary in order for competitors to plan their rollout. On request, the incumbent will also need to provide data for each proposed circuit so that operators can assess whether they are likely to be able to provide a given customer with broadband access. The incumbent has a natural incentive to keep such information about his network topology secret[218]: 1) To impede the rollout by entrants 2) To prevent entrants from engaging in cream-skimming.

In Canada e.g. entrants have access to collocation at all the incumbent's central offices, without a requirement that a specific customer has ordered a connection.

8.5.2 Universal service of broadband and rollout requirements

Legislators also have to consider whether to extend the universal service requirement to cover broadband access as well - whether broadband access has to be available to all citizens at affordable prices - an initiative, which is likely to be advocated by consumer groups and many politicians. However, this would require network operators to either rollout or upgrade their network also in areas, which are not yet economic to serve, thus resulting in higher prices. Rollout requirement may therefore actually deter investment and should therefore be limited to a minimum. If politicians want to ensure broadband access to certain consumer such as e.g. schools and libraries it seems more appropriate to subsidise such access directly via public funds.

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[217] According to Telia, an entrant telecom operator in Denmark, the incumbent Tele Danmark is e.g. only willing to provide Telia with a level of power, corresponding to an "ordinary vacuum cleaner" at the switches. This prohibits Telia from installing equipment for ADSL (broadband access via existing copper line) at the switches to compete with Tele Danmark (Børsen 1.11.1999). And in a folder from Tele Danmark it was written that a buyer had to subscribe to the internet service of Tele Danmark (Opasia) and have a regular phone or ISDN subscription with Tele Danmark in order to buy its new cable modem (Børsen 1.11.1999)[217]. It is difficult for the regulator to foresee these kind of anti-competitive actions. With regard to technical issues and delays, it may also be difficult for a regulator to evaluate whether the claims of the incumbent are justified or not.

[218] In Denmark the incumbent Tele Danmark, has so far managed to keep this kind of information secret. But according to a recent proposal for a new telecom legislation, Tele Danmark will be required to provide entrants seeking interconnection with such information about how the local loops are connected to the local switch, the length and quality of the lines etc. Comments on § 61 of Bill L248 of 30 March 2000 on law about competition and consumer issues for telecommunications, http://www.fsk.dk/fsk/div/love/l248.doc

The regulator also has to consider whether the unbundling requirement should be extended to entrants and whether other kinds of local access lines such as e.g. fibre, cable and wireless local loops should be unbundled as well. More on this below.

8.6 LLU and real-option theory

As argued in chapter 7, one of the main insights of real-option theory is that if legislators wish to encourage investment, regulatory uncertainty should be minimised. This argues in favour of requiring LLU as quickly as possible unless one can commit to not introducing such a requirement later on. Another important insight is that a regulated price equal to LRIC is not enough to provide firms with efficient investment incentives in case the investment is irreversible, uncertainty is present and the firm has managerial flexibility to postpone the investment. Some will argue that investment in local access infrastructure either is not irreversible, uncertain or can not be postponed. In some cases, the assumptions may indeed only be partly correct. But as long as the three assumptions are partly correct the firms will still have to be allowed some premium to cover the lost option value associated with investing today instead of postponing the investment decision.

However, with regard to unbundled local copper loops, already in the ground, the investment has already been undertaken. An option premium is therefore unnecessary. In option terms one could say that the value of the option to wait is zero. Adding an option premium on top of LRIC would only imply a transfer of wealth from entrants (consumers) to the incumbent.

It is true, of course, that the entrants' incentives to invest in alternative infrastructure are reduced compared to a situation where local loops were priced above LRIC. From an efficiency-point-of-view, however, this bias is appropriate because society does not face any opportunity cost when renting the copper already in place, while such an opportunity cost exists for investments in alternative infrastructure. Biasing the decision in favour of investing in alternative infrastructure would simply imply that society incurred otherwise avoidable opportunity costs, duplicating the existing infrastructure[219]. Therefore a price based on LRIC+[220] alone is appropriate for the existing local copper loops.

[219] If such duplication is called for due to a future demand for multiple access lines, the problem is of course reduced.

With regard to new investments, however, the option value becomes important. If entrants, contemplating investment in competing access networks based on alternative technologies such as FWA, UMTS, upgraded CATV etc. are also required to give competitors access to their infrastructure at LRIC based prices, investment incentives are likely to be hampered. If these firms are only allowed to cover LRIC, investment may be postponed until uncertainty about demand, investment costs, technology etc. has been reduced. To the extent that consumers are willing to pay a price for these new services that exceeds LRIC, a welfare loss will consequently be incurred. Second, firms may choose not to invest at all, based on the logic that if the investment succeeds they are only able to cover their costs and earn a reasonable profit, whereas if the investment fails, they are the only ones to cover the loss. Unless the chance of failure is small, expected surplus will then be negative. The same reasoning applies to investments in upgrading the incumbents network. Finally, from a strategic point of view it is very unattractive having to support competitors to compete against you.

Similarly, entrants should only be allowed access to pre-existing lines at LRIC prices. They should not be able to force the incumbent to invest in new (second) lines. If entrants were allowed such a possibility, their decision between requiring such an investment of the incumbent and building it themselves, would be biased towards renting the line, keeping alive the option to later invest themselves.

Due to the negative impact on investment incentives, an unbundling requirement at cost-based prices should only apply to operators with significant market power. Perhaps, it should only be applied to operators with a dominant market power in the relevant market. The latter would be consistent with general competition law.

[220] Just to avoid misunderstandings, the reader is reminded that "+" refers to the markup for joint and common costs and has nothing to do with the option premium. Here LRIC and LRIC+ are used interchangeably depending on whether the focus in on the methodology (LRIC) or the actual price that should be applied (LRIC+).

Chapter 9

Conclusion

To introduce competition into network industries, such as e.g. the telecommunications industry, it is necessary to allow entrants access to the incumbent's network. The reason is that these industries are characterised by large economies of scale and density, which make investments in competing networks - in particular access networks - uneconomical. (Fixed) access provision thus constitutes a natural monopoly. The local access network is an essential facility to which entrants need access one way or the other. In telecom, such access (interconnection) is furthermore required because entrants in order to offer a competing product needs the ability to terminate calls on the incumbent’s network.

Absent regulation, the incumbent has strong anti-competitive incentives to refuse access/interconnection or at least has incentives to impose disadvantageous terms on entrants, such as e.g. a high access/interconnection price. First of all to earn a monopoly rent on access provision of which he (the incumbent) enjoys a monopoly, and second to increase the cost of competitors in order to gain a competitive advantage in the retail market. To avoid such an abuse of dominance, regulation of access and, in particular, the price of such access is required. The highly asymmetric distribution of bargaining power calls for sector-specific regulation in order to "level the playing field". It is not enough to rely on general competition law alone.

To obtain allocative and productive efficiency, while at the same time providing incumbents and entrants with efficient investment incentives, the access/interconnection price should be set equal to (forward-looking) long run average incremental costs (LRAIC) plus a mark-up to cover joint and common costs including a reasonable profit. In theory, this is the price that would prevail if access provision was produced in a competitive market and it is thus consistent with the gradual move towards full competition.

Estimating LRAIC correctly, however, is a complicated and time-consuming task. A practical alternative to LRAIC is therefore needed, at least temporarily. Such an alternative could be the use of the kind of benchmark regulation known as "best current practice", where the price of an access service is set equal to the lowest national or international price of that service. The presumption is that this price best reflects LRAIC. Regulators should keep in mind, though, the risk that the resulting prices may actually turn out to be below LRAIC. Especially, if the relevant benchmark country is allowed to differ for each particular access or interconnection service. If the various interconnection services are cross subsidised differently across the benchmark countries, there is a risk of *cherry picking* where regulators or entrants pick the most cross-subsidised interconnection services in each country. If the incumbent subsequently is subjected to all these best-practice prices, he will not be able to cover his (LRAIC) costs. The same will be true if cost differences between the benchmark countries are significant e.g. due to differences in density, geographic topology, labour costs etc. On the other hand, to allow the incumbent to correct for all these differences, like it has been proposed in Denmark, provides the incumbent or the regulator with substantial discretionary powers. To avoid this, it seems appropriate instead to use the "best-current-practice", originally proposed by the Commission, where the price is calculated based on prices from a group of the cheapest countries, say the three cheapest, and then in turn apply the rule more mechanically.

Allowing entrants access to the incumbent's network at cost-based wholesale prices creates a potential problem of cream-skimming if the incumbents retail tariffs are not fully rebalanced to reflect costs. Hence, any cross-subsidy schemes that might be in place will gradually be undermined because the incumbent with the universal service requirement will be left with all the unprofitable customers. The incumbent should therefore be allowed to fully rebalance his tariffs. To minimise the harm on low-usage (low-income) customers and customers living in high cost (rural) areas, it is appropriate to establish a Universal Service Fund[221] to which all customers contribute, whether or not they bypass the incumbents network. Access charges should not be allowed to include contributions to fund the Universal Service Obligation (USO).

To minimise the burden of the USO and to avoid subsidising profitable consumers, the cost of the USO should be calculated on a net basis - the difference between the costs of operating under the USO and the cost of operating without it. It is also appropriate to combine tariff rebalancing with the introduction of low-user schemes, to which low-usage (low-income) consumers can self-select.

[221] Of course, only if there is a net cost associated with holding the Universal Service Obligation.

With regard to basic voice telephony, entrants have already today access to compete against the incumbent on an almost level playing field due to the recent introduction of carrier pre-selection and number-portability. However, with the development of broadband access technologies such as ADSL and products, combining mobile and fixed telephony, such as "Duet", competitors increasingly require direct access to the essential facility itself - the unbundled local loop - in order to provide a product that can compete with that of the incumbent. Access to ULLs also increases local competition and allows entrants to introduce innovative pricing schemes for basic voice telephony as well.

Based on a somewhat simplistic legal analysis, it was concluded that access to the ULLs could not be mandated based on EU competition law and the EU essential facility doctrine alone. Thus sector-specific regulation on LLU is required.

A main objective of the thesis was to consider the regulatory implications of introducing uncertainty into the problem of access pricing. Based on a formal analysis, which drew out the relevant insights of real-option theory and extended these insights to the problem of access pricing (or regulation in general), is was inter alia concluded:

First, that regulatory uncertainty about a possible LLU-requirement could represent a main impediment to investments in network infrastructure for entrants as well as for the incumbent. Due to the substantial and increasing arguments in favour of LLU as well as the impossibility of a commitment not to introduce a LLU-requirement in the future, legislators/regulators should therefore quickly establish a transparent regulatory framework for LLU in all Member States.

Second, if access provision by a regulated operator requires investments in either upgrading an existing network or in constructing a competing network, and these investments 1) are irreversible, 2) involves uncertainty over future net revenues and 3) can be postponed; then the regulated (access) price, in order to create efficient (dynamic) investment incentives, needs to include an option premium on top of LRIC to compensate the regulated operator for the lost option value, associated with investing today instead of waiting until some of the uncertainty is resolved. This insight applies to regulation in general, not only to regulation of access prices.

With regard to the local loops, already in the ground, such an option premium would not affect investment incentives but would rather imply a transfer of wealth from entrants to the incumbent, thus contradicting the need for levelling the playing field. Hence an option premium should not be added. The rental price should be set equal to LRIC plus a mark-up to cover joint and common costs, including a reasonable profit on the invested capital.

On the other hand, if regulators want to regulate the price of access to alternative (future) access networks based on technologies such as cable television, UMTS and FWA technologies this option value cannot be ignored. Estimating these option premiums correctly, however, is at best very complicated. A practical solution is to allow a relatively short depreciation horizon. But to the extent that multiple access networks are indeed constructed, it seems more appropriate not to regulate access to these networks at all and instead leave the question to industry negotiation subject only to general competition law - in particular the requirement for non-discrimination.

Despite the technological development of competing access technologies, there is a risk that the local loop will remain an essential facility in many years to come. First of all because new technologies such as ADSL increase the capability of the loops dramatically, secondly, because the cost effectiveness of alternative broadband technologies remains to be seen. To increase regulatory certainty and to spur entry, it therefore seems inappropriate to limit the period of the LLU-requirement. Rather than deciding on a specific date to end the LLU-requirement, regulators should establish the guidelines for termination of such a requirement. Such guidelines should include a minimum notification period, say two-three years, as well as the basis for such termination, say a market share (of the wholesale market) below XX%.

When multiple entrants have established points of interconnection at the incumbents local switches/main distribution frames, competition should prevail on all services except for loop provision and call termination. Call termination will remain quasi monopolistic as long as the calling party is paying for call termination because the calling (and paying) party has no choice regarding which operator that terminates his call. Call termination should therefore be regulated for all operators, not only operators with a significant market share as it is the case today in most, if not all, EU Member States.

Regulators can then focus on regulating call-termination charges, the rental charges for access to the unbundled local loops and possibly operation of a Universal Service Fund and low-usage schemes. It should be possible to gradually withdraw the current regulation of retail prices as well as the regulation of interconnection tariffs for simple transit and eventually also for call origination, which may perfectly well be delivered by a competitive market. If full infrastructure competition arrives as well, only call termination will have to be regulated.

In countries where current retail rental prices are substantially below LRIC+ due to the fact that retail rental prices are set according to historic costs, it may be appropriate to gradually move from a ULL-price based on historic costs to a price based on current (LRIC+) costs.

In countries with large geographic cost differences it seems inappropriate to require geographically averaged prices for ULLs, even though geographically de-averaged prices will eventually undermine the geographically averaged retail prices. Consumers in high cost areas may instead be subsidised directly through a Universal Service Fund. Costs and subsidies should be calculated on a net basis in order to avoid subsidising profitable lines.

Due to the ongoing convergence between mobile telecom, fixed telecom, IT and the media sector, there is a need for gradual withdrawal of sector-specific regulation and increased reliance on a common and more flexible framework such as general competition law (at least regarding infrastructure). This is necessary to achieve technology neutrality and the flexibility necessary to deal with the rapid technological development.

To follow up on the option analysis provided in this thesis, it would be interesting to see future empirical research on how LLU-requirements, different prices and time limits in practice affect incentives to invest in alternative infrastructure, in collocation and in upgrading the incumbent's network. The effect on market-determined end-user prices and wholesale prices should be investigated as well. Finally, it would be interesting to see research evaluating the degree of uncertainty and managerial flexibility associated with investment in telecom access networks.

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Appendix A:

Article 81, 82, 86 and 154 of the European Treaty[222]

Relevant articles on competition law:

Article 81 (ex 85)

1. The following shall be prohibited as incompatible with the common market: all agreements between undertakings, decisions by associations of undertakings and concerted practices which may affect trade between Member States and which have as their object or effect the prevention, restriction or distortion of competition within the common market, and in particular those which:

    (a) directly or indirectly fix purchase or selling prices or any other trading conditions;
    (b) limit or control production, markets, technical development, or investment;
    (c) share markets or sources of supply;
    (d) apply dissimilar conditions to equivalent transactions with other trading parties, thereby placing them at a competitive disadvantage;
    (e) make the conclusion of contracts subject to acceptance by the other parties of supplementary obligations which, by their nature or according to commercial usage, have no connection with the subject of such contracts.

2. Any agreements or decisions prohibited pursuant to this Article shall be automatically void.
3. The provisions of paragraph 1 may, however, be declared inapplicable in the case of:

    - any agreement or category of agreements between undertakings;
    - any decision or category of decisions by associations of undertakings;
    - any concerted practice or category of concerted practices,

    which contributes to improving the production or distribution of goods or to promoting technical or economic progress, while allowing consumers a fair share of the resulting benefit, and which does not:

    (a) impose on the undertakings concerned restrictions which are not indispensable to the attainment of these objectives;
    (b) afford such undertakings the possibility of eliminating competition in respect of a substantial part of the products in question.

Article 82 (ex 86)

Any abuse by one or more undertakings of a dominant position within the common market or in a substantial part of it shall be prohibited as incompatible with the common market insofar as it may affect trade between Member States.

Such abuse may, in particular, consist in:

    (a) directly or indirectly imposing unfair purchase or selling prices or other unfair trading conditions;

[222] The whole treaty is available at http://europa.eu.int/eur-lex/en/treaties/index.html

(b) limiting production, markets or technical development to the prejudice of consumers;
(c) applying dissimilar conditions to equivalent transactions with other trading parties, thereby placing them at a competitive disadvantage;
(d) making the conclusion of contracts subject to acceptance by the other parties of supplementary obligations which, by their nature or according to commercial usage, have no connection with the subject of such contracts.

Article 86 (ex 90)

In the case of public undertakings and undertakings to which Member States grant special or exclusive rights, Member States shall neither enact nor maintain in force any measure contrary to the rules contained in this Treaty, in particular to those rules provided for in Article 12 and Articles 81 to 89.

1. Undertakings entrusted with the operation of services of general economic interest or having the character of a revenue-producing monopoly shall be subject to the rules contained in this Treaty, in particular to the rules on competition, insofar as the application of such rules does not obstruct the performance, in law or in fact, of the particular tasks assigned to them. The development of trade must not be affected to such an extent as would be contrary to the interests of the Community.

2. The Commission shall ensure the application of the provisions of this Article and shall, where necessary, address appropriate directives or decisions to Member States.

Relevant article on Trans-European Networks

Article 154 (ex 129b)

1. To help achieve the objectives referred to in Articles 7a and 130a and to enable citizens of the Union, economic operators and regional and local communities to derive the full benefit from the setting up of an area without internal frontiers, the Community shall contribute to the establishment and development of trans-European networks in the areas of transport, telecommunications and energy infrastructures.

2. Within the framework of a system of open and competitive markets, action by the Community shall aim at promoting the interconnection and inter-operability of national networks as well as access to such networks. It shall take account in particular of the need to link island, landlocked and peripheral regions with the central regions of the Community.

Appendix B:

Dynamic programming for valuing real options[223]

If uncertainty over π, V cannot be spanned by existing assets as assumed in section 6.4.3, then we are unable to construct a risk-free portfolio. Instead we can use dynamic programming with a pre-specified discount rate, ρ. This approach is illustrated below:

The value of the investment if made today, $V(\pi)$, is found just like in section 6.4.2 and the option to invest is still called F(V).

We start with a value of V in the range (0,V*) - corresponding to a value of π in the range $(0,\pi^*)$. At such a value it is optimal to postpone the investment - to hold onto the option. We choose an interval dt, which is sufficiently small to ensure that it will continue to be optimal to hold onto the option at the end of this interval.

The value of the option to invest must then equal the sum of the revenue generated by holding the option over the this interval, dt, and the option's expected (E[..]) value by the end of the interval discounted with ρdt:

$$F(V) = 0 + E\,[F(V) + dF]e^{-\rho\,dt} = (1-\rho\,dt)(\,F(V) + E[dF]\,)^{224} \qquad \text{(B.1)}$$

The '0' expresses the fact that an option, as opposed to the underlying asset (the investment), does not generate any revenue as long as we just hold on to it. dF is the change in F(V) during the interval dt.

We now expand dF, using Ito's lemma:

$$dF = F'(V)dV + \tfrac{1}{2}\,F''(V)\,(dV)^2$$

Then we insert dV (equation 6.3) in the first term and find the expected values.

$$E(dF) = F'(V)\,E[\alpha V dt + \sigma V dz] + \tfrac{1}{2}\,F''(V)\,E[(dV)^2] = F'(V)\,\alpha V dt + \tfrac{1}{2}\,F''(V)\,\sigma^2 V^2 dt$$

[223] Before reading this appendix, the reader should read through section 6.4.

[224] We have used the approximation $e^{-\rho\,dt} = (1-\rho dt)$, which holds for dt close to 0.

We have used the fact that $E(dz) = 0$ and $E[(dV)^2] = E[\alpha^2V^2(dt)^2 + \sigma^2V^2(dz)^2 + \alpha\sigma dtdz] = \sigma^2V^2dt$. The latter is true because terms, which include dt in a higher order than 1 are eliminated when $dt \rightarrow 0$ and because $dtdz=dt^{3/2}$ and $E[(dz)^2] = dt$.

Then we insert E(dF) in equation B.1. Again we use the fact that that terms with dt in a higher order than 1 disappear.

$$F(V) = (1-\rho dt)[\, F(V) + F'(V)\, \alpha V dt + \tfrac{1}{2} F''(V)\, \sigma^2V^2dt \,] \Leftrightarrow$$
$$F(V) = F(V) + F'(V)\, \alpha V dt + \tfrac{1}{2} F''(V)\, \sigma^2V^2dt - \rho dt\, F(V)$$

Finally, we rearrange and divide through by dt:

$$0 = F'(V)\, \alpha V dt + \tfrac{1}{2} F''(V)\, \sigma^2V^2dt - \rho dt\, F(V) =$$
$$0 = \tfrac{1}{2} F''(V)\, \sigma^2V^2 + \alpha F'(V)\, V - \rho\, F(V) \qquad \text{(B.2)}$$

Equation B.2 is a quadratic equation similar to equation 6.4 in chapter 6, restated here:

$$\tfrac{1}{2} F''(V)\, \sigma^2V^2 + (r_f - \delta)\, F'(V)\, V - r_f\, F = 0 \qquad \text{(6.4)}$$

To ease comparison we make the substitution $\alpha = \rho - \delta$ in B.2[225]:

$$\tfrac{1}{2} F''(V)\, \sigma^2V^2 + (\rho - \delta)\, F'(V)\, V - \rho\, F(V) = 0 \qquad \text{(B.3)}$$

We see that the only difference between B.3 and 6.4 is that r_f is replaced by ρ.

By applying the same boundary conditions as in chapter 6 - equations (6.5), (6.9) and (6.10) - we would find a similar investment rule to that of chapter 6:

Invest when $V_t \geq V^* = \dfrac{b_1}{b_1 - 1} I$, only now with $b_1 = \dfrac{1}{2} - \dfrac{r - d}{s^2} + \sqrt{\left[\dfrac{r - d}{s^2} - \dfrac{1}{2}\right]^2 + \dfrac{2r}{s^2}} > 1$

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[225] Remember that α is the expected growth rate of π and V per period. δ is some kind of convenience yield from holding the underlying asset. The total revenue from holding the underlying asset is therefore $\alpha + \delta$, which in equilibrium must equal the cost of capital, ρ, (otherwise there would be arbitrage). Hence, the relationship $\alpha = \rho - \delta$.

Appendix C:

Status of Local Loop Unbundling in the EU, the US and Canada:

	Status of LLU (monthly rental of copper pair where available, ex VAT)	**Basis for price of ULLs**
Austria	12 Euro/month	Price based on current valuation of assets
Belgium	Consultation	
Denmark	8.23 Euro/month	Price based on historic costs[226]
Finland	5-25 Euro/month	Price based on current valuation of assets
France	Under consideration	
Germany	13 Euro/month	Price set by Reg TP based on Forward Looking LRAIC
Greece		
Ireland	Consultation	
Italy	Proposed by 2000	
Luxembourg		
Netherlands	Less than 14.4 Euro/month	Gradual move from historic cost to current cost
Portugal		
Spain	Line sharing access can be negotiated	Phased pricing set by OPTA, moving from historic costs to current costs in 5 years
Sweden	Proposed by 2000	Price proposed to be based on current costs
UK	From July 2001. Price likely to be about 13 Euro/month	Oftel will set price based on Forward Looking LRAIC

Source: Commission (2000): Working Document of DG13 (INFSO) A1 on "Unbundled access to the local loop", 9 February 2000.http://bscw2.ispo.cec.be/infosoc/telecompolicy/en/ullwd10b.doc

US: Unbundling requirement on all network elements including the local loops at TELRIC.
The FCC decided that rates for interconnection and unbundled elements must be geographically de-averaged, where there are significant cost variations.

Canada: Time limited (5 year) unbundling of the local loops in urban areas at LRIC+. Unlimited in rural areas. Somewhat geographically de-averaged prices.[227]

[226] Has been corrected from the working document, which stated that the price was based on telephone line rental.
[227] FCC (1998) Local competition. VII. Pricing of interconnection and unbundled elements, B3(c), 4 December 1998, http://www.fcc.gov/ccb/local_competition/sec7.html, Telephone interview with an employee at the CRTC.

Appendix D

Useful web-sites[228]

California Public Utility Commission (CPUC) - Telecommunications Division
http://www.cpuc.ca.gov/telecommunications/teledisc.htm

Danish Ministry of Research and Information Technology (Forskningsministeriet): http://www.fsk.dk

Danish Parliament (all legislation available): http://www.folketinget.dk

DG4 (Competition) of the European Commission - Liberalisation, Implementation page:
http://europa.eu.int/comm/dg04/lawliber/libera.htm

DG13 (Information Society) - Page on Convergence of the Telecommunication, Media and Information Technology sectors: http://www.ispo.cec.be/convergencegp/

DG13 (Information Society) - EU Telecommunication Policy page:
http://www.ispo.cec.be/infosoc/telecompolicy/Welcome.htm

DG13 (Information Society) - Studies and reports to the European Commission:
http://www.ispo.cec.be/infosoc/telecompolicy/en/Study-en.htm

DG17 (Energy and Transport) - The single market for electricity:
http://europa.eu.int/en/comm/dg17/elechome.htm

DG17 (Energy and Transport) - The single market for natural gas:
http://europa.eu.int/en/comm/dg17/gashome.htm

European Interconnect Atlas - EU Regulatory framework + Info on Interconnection in Member states: http://www.analysys.com/atlas

EUR-LEX (EU law): http://www.europa.eu.int/eur-lex/en/index.html

European Court of Justice and Court of First Instance: http://curia.eu.int

ETO links (inter alia to telecom regulators around the world): http://www.eto.dk/links.htm

FCC - Local Competition site: http://www.fcc.gov/ccb/local_competition/

Network economics site by Nicholas Economides: http://raven.stern.nyu.edu/networks

Oftel (UK NRA) - Network and Interconnection: http://www.oftel.gov.uk/isp/netint.htm

Reg TP (German NRA): http://www.regtp.de/

Telestyrelsen (Danish NRA): http://www.tst.dk

[228] Available on-line at http://www.image.dk/~holmside/web-sites.htm

Appendix E

Abbreviations

ADSL - Asymmetric Digital Subscriber Line (broadband access via copper line)

ASAC - Average Stand Alone Costs

CATV - Cable Television

CAPM - Capital Asset Pricing Model

ECJ - European Court of Justice

ECPR - Efficient Component Pricing Rule

FDC - Fully Distributes Costs

FWA - Fixed Wireless Access

LLU- Local Loop Unbundling

LRIC - Long Run Incremental Costs

LRIC+ - LRIC plus a mark-up for joint and common costs, including a reasonable profit

LRAIC - Long Rung Average Incremental Costs

MES - Minimum Efficient Scale

NRA - National Regulatory Authority

TELRIC - Total Element Long Run Incremental Costs

TSLRIC - Total Service Long Run Incremental Costs

MDF - Main Distribution Frame

ONP - Open Network Provision

POI - Point of Interconnection

ULL - Unbundled Local Loop

UMTS - Universal Mobil Telecommunications System (3^{rd} Generation mobile)

USF - Universal Service Fund

USO - Universal Service Obligation